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Bovine Tuberculosis in Cervidae: Proceedings of a Symposium

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Bovine Tuberculosis in Cervidae: Proceedings of a Symposium

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Foreword

Bovine tuberculosis in captive Cervidae was first recognized as a problem in the United States in late 1990, when elk exported to Canada were reported to have introduced the disease into a cervid herd there. The issue was highlighted shortly thereafter by Canada's ban on cervid imports for any purpose from the United States. The efforts of the Animal and Plant Health Inspection Service (APHIS) to deal with the herd of origin of these elk quickly revealed the deficiencies in our knowledge about tuberculosis in this family of animals and about the cervid industry. Also, our vulnerability to the spread of bovine tuberculosis by cervids was soon apparent, as was the great potential cervid tuberculosis presents for major setbacks in our national bovine tuberculosis eradication program. When this crisis began, we had no appreciable resources at our disposal, no regulations dealing with Cervidae nor recognized authorities for their formulation, no program in place, and no funds for compensating owners for animals destroyed because of tuberculosis. In that environment, APHIS embarked on an effort to stem the spread of bovine tuberculosis in the deer industry.

The International Conference on Bovine Tuberculosis in Cervidae was held to help correct some of these deficiencies and to provide an information base upon which future decisions could be made about managing the problem. The conference provided a forum to exchange current information, present new knowledge on tuberculosis in these species, and share experiences and program progress in countries successfully dealing with the disease. The conference also provided a setting for the purpose of bringing together industry representatives and producers, recognized authorities on tuberculosis and on cervid husbandry, scientists and educators, wildlife and zoo specialists, and tuberculosis specialists in human medicine, in addition to State and Federal animal health officials. Most essential was the participation and input of industry representatives and producers in whose herds and facilities the policies and procedures shaped here would soon be carried out.

The chief objective of this conference was to formulate recommendations for dealing with defined problem areas, namely: testing and followup procedures, animal movements, research needs, compensation, zoos and exotic animal collections, and human health concerns. The measure of success of this forum is the quality of the recommendations forwarded. The recommendations show clearly the wisdom of the collective mind made possible when knowledgeable, concerned persons work toward the solution of a common problem. In the intervening period we have used these recommendations as the principal guide for shaping policy and procedures, and have deviated from them on the side of safety only when deemed prudent.

APHIS remains committed to eradicating bovine tuberculosis from the United States. No longer can it be contested that captive cervids are raised for legitimate agricultural pursuits. Nor can it be contested that any successful effort toward disease control also requires the commitment and resolve of the industry, and of the State animal health agencies. With these commitments clearly in place, it becomes our common challenge to proceed on the wisest possible course toward control leading to the eradication of bovine tuberculosis from cattle, bison, and captive cervids in the United States.

—Billy G. Johnson
Deputy Administrator
Veterinary Services

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Bovine Tuberculosis in Captive Cervidae in the United States

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Introduction

Bovine tuberculosis in Cervidae became an important issue in the United States during 1991. The farming of captive deer and elk is a comparatively recent, but rapidly growing, industry in this country. Extensive animal movements are a characteristic of the industry. Animal movement contributes more to widespread distribution of disease than any other single factor.

The United States' involvement with tuberculosis in these species followed a report from Canada in late 1990 that *Mycobacterium bovis* had been isolated from elk that had died of tuberculosis following importation from the United States in 1988. Canada closed its borders in November 1990 to the importation of Cervidae from the United States. In December 1990, the testing procedure for deer and elk was changed, making the cervical tuberculin test the standard test in lieu of the caudal-fold tuberculin test. The neck skin is considerably more sensitive to tuberculin than is the caudal fold. Without a program, without authorities to control movements, without funds for operations or indemnities, the United States commenced cervid tuberculosis control procedures, all under State authorities.

I would like to review the recent history of bovine tuberculosis in Cervidae in the United States briefly and present the current status of the disease. I will also discuss epidemiology and some of the findings that have emerged from our investigations in progress. But first, to place the current outbreak in cervids into proper perspective, I will briefly discuss the status of this disease in the traditional domestic livestock of the United States.

Tuberculosis in Cattle and Bison

Since the onset of the National Cooperative State–Federal Bovine Tuberculosis Eradication Program in 1917, we have progressed from a 5-percent prevalence of tuberculosis in the Nation's cattle population to the point of virtual eradication of this disease. Bovine tuberculosis was by far the most prevalent infectious disease of cattle and affected almost 15 percent of the swine population as well. In 1917, in less than 10 million cattle inspected at slaughter, 200,000 carcasses were retained for suspected tuberculosis. Of those, 30,000 were condemned. Tuberculosis was also prevalent in the human population.

Currently, 41 States plus the U.S. Virgin Islands have Accredited-Free status and the remaining 9 States plus Puerto Rico have Modified-Accredited status. An average of 12 infected herds have been detected annually over the past 10 years, and an average of 140 carcasses[1] per year have been detected with tuberculosis in the more than 36 million slaughter cattle inspected annually over the same 10-year period.

Bovine tuberculosis has been eradicated from swine, bison, sheep, and goats in this country. The disease in the indigenous human population of the United States is of historical interest only, having been confirmed in the past two decades only in immigrants and in persons visiting foreign countries for extended periods. *M. bovis* is not known to exist in any domestic species other than cattle or in any species of wildlife, nor in any nontraditional livestock species except for cervids on farms. It is into this framework of a highly successful tuberculosis eradication program that any control or eradication measures developed for cervids must fit.

[1] Approximately 70 percent of the 1,400 tuberculous cattle detected on regular slaughter inspection between 1982 and 1991 were traced back to Mexico.

History in Cervids

During the past 30 years, very few significant events occurred involving tuberculous cervids. The earliest case involved a fallow deer herd in Michigan in 1962 that was reported by J. Quinn, D. Towar, and others. After a long period of cervical tuberculin testing with removal of reactors, followed later by isoniazid treatment, this herd dropped from sight. The herd reappeared approximately 10 years later in southern California, where it was again found to be infected with *M. bovis*. The herd ended its existence at the University of California, Davis, as subjects for experimental tuberculosis testing procedures. Most of these animals revealed lesions of tuberculosis on necropsy. This event provided our earliest indication of the tenacity of *M. bovis* infection in cervids.

The second important event occurred in 1973, beginning with a report from Canada that exotic sheep that had originated from a game farm in the Eastern United States had died of tuberculosis. The investigation of the game farm disclosed extensive tuberculosis in several species of the family Cervidae and in other species. Tuberculosis was later traced back to this game farm from other outbreaks of the disease in cervids and antelopes in the United States.

In 1981, *M. bovis* was confirmed in an elk herd in South Dakota and in two additional elk herds intected from that herd. The most likely source of tuberculosis in the index herd was believed to be the 1978 addition of two elk that had originated in a small zoo in another State. In 1984, bison that were associated with the index South Dakota elk herd were found to be infected with *M. bovis*. Much movement had occurred from this bison herd. The Code of Federal Regulations was quickly amended to include bison as cattle for all tuberculosis provisions. The ensuing investigations, which involved 25 States, led to a total of 24 infected bison herds located in 10 States, 7 of which held Bovine Tuberculosis Accredited-Free status.

The investigations were conducted over a 2-year period. No further evidence of tuberculosis has since been detected in the bison industry.

This event clearly established the role of captive deer and elk in the epidemiology of bovine tuberculosis in domestic livestock. There is no evidence at this time of bovine tuberculosis in wild Cervidae in the United States. To our knowledge, there are no species of wildlife in the United States in which *M. bovis* is known to exist. Wildlife surveys are planned, however, to determine whether tuberculosis may have escaped into native cervids. These surveys will utilize hunter-killed elk in the proximity of an infected captive cervid herd in western Colorado and in Montana near Yellowstone National Park.

Current Status

Our investigation of the possible role of the United States' captive cervid herds as it relates to Canada's newly found tuberculosis problem established a positive linkage between an elk herd in Montana and an important index herd in Canada. Subsequent movements of tuberculosis-infected and exposed elk from the Canadian herd involved several additional cervid herds in Alberta Province. During fiscal year (FY) 1991, bovine tuberculosis was confirmed in 10 cervid herds in the United States located as follows: Montana, 3; and one each in Colorado, Idaho, Nebraska, Oklahoma, Texas, Wisconsin, and New York. Confirmation of disease is also pending in at least one herd in Washington and another in Montana (fig. 1). Epidemiologic linkages have been established among all infected and pending herds located in Montana, Nebraska, Colorado, Idaho, and Washington. Epidemiologic investigations of infected herds indicate that the captive cervid industry is characterized by extensive movements of breeding stock, enhancing the likelihood of widespread distribution of tuberculosis-infected and exposed animals.

Epidemiology

Epidemiologic tracing produced some interesting results and clearly established the risk presented by captive Cervidae to cattle and bison, the official species included in the tuberculosis eradication program. These investigations will also illustrate the enormous spread potential of bovine tuberculosis with the movement of tuberculosis-exposed animals.

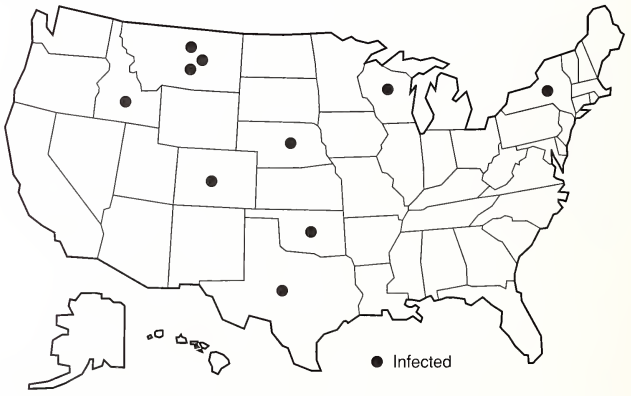
Figure 2 depicts a 1990 traceback of a tuberculous cow detected at regular slaughter that led to a cattle herd in Nebraska. Though tuberculosis has yet to be confirmed in that herd, *M. bovis* infection was confirmed in an adjacent cattle herd that had previously been associated with elk. These elk were later proven to be tuberculous. The elk had moved from the infected Nebraska herd to Montana Herd A in 1987 and moved again to Colorado Herd C only 2 months later. These elk were depopulated in Colorado Herd C in June 1991 and were found to have extensive tuberculosis lesions. The lesions found in Herd C were considerably more extensive than seen to date in Montana Herd A, suggesting that the Nebraska elk herd was the source of Montana Herd A's infection. It was from Montana Herd A that elk moved in 1988 to the index Canadian herd, where they were confirmed infected with *M. bovis* in 1990.

The Nebraska owner had assembled this elk herd in 1981 from two sources, Montana Herd B and Iowa Herd E. As it was later discovered, Iowa Herd E was the same source of two elk believed to have introduced *M. bovis* into the South Dakota bison herd in 1978 (fig. 3). These elk entered Iowa Herd E from a small, now-defunct exotic animal collection. The owner of the South Dakota elk herd reported that these two animals were sick when he acquired them in 1978 and died shortly thereafter. This event was followed by a series of elk deaths of unknown cause until *M. bovis* was confirmed on this elk farm in 1981.

Back to the Nebraska source herd. The investigation of this case disclosed that death losses began within months of the 1981 herd assembly. The third elk that died was necropsied at a regional veterinary diagnostic laboratory in Nebraska. It was discovered that fixed tissues from this animal

Figure 1

Cases of bovine tuberculosis in Cervidae during fiscal year 1991



were still available in 1991. Histopathologic examination of these tissues in 1991 showed clearly that the animal had generalized tuberculosis. At this time it is only speculative, but two sick elk from a small zoo may have introduced *M. bovis* to Iowa Herd E and later moved on to infect the South Dakota elk/bison herd, accounting for the situation depicted in figure 3. Equally speculative is the conclusion that Iowa Herd E may have also been the source of infection of the Nebraska index herd, which is believed to have infected Montana Herd A, which was itself linked to the Canadian index herd from which tuberculosis-exposed animals had moved to additional herds in Alberta and Saskatchewan Provinces. Investigations in progress may help clarify the role of Iowa Herd E, from which a substantial number of movements have been identified since 1981.

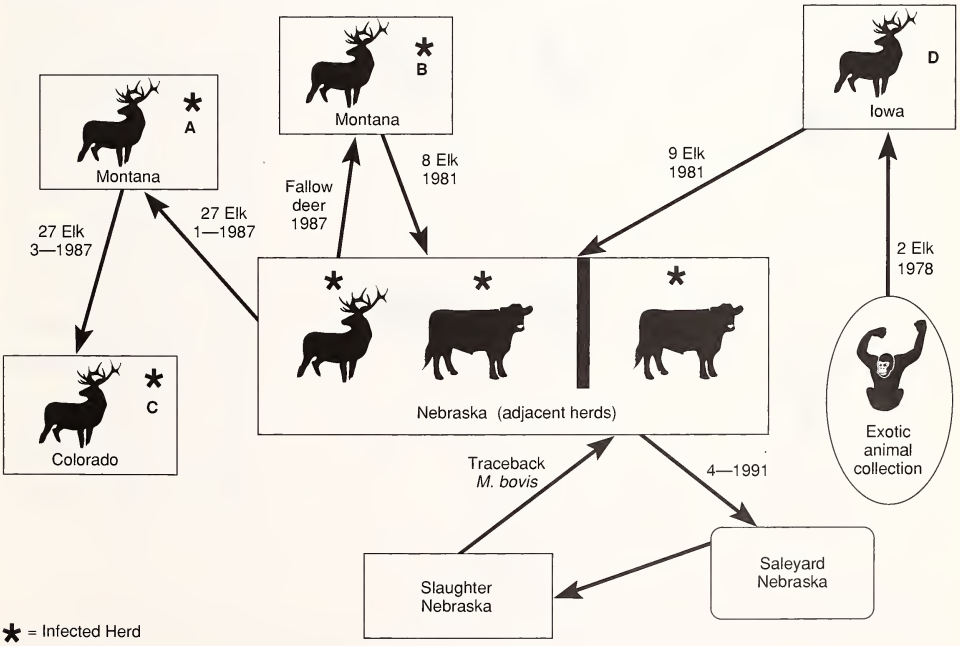
Problem Areas

At this time, no authorities have been identified to regulate the interstate movement of Cervidae for tuberculosis. There is no Federal program in the United States, nor have sources of funds been identified for compensating owners for animals destroyed because of tuberculosis. Consequently, all activities related to managing the existing tuberculosis situation in cervids are conducted under State authorities. These authorities vary greatly with regard to movement control, quarantine, testing requirements, and allowable indemnities.

These conditions have resulted in an almost untenable position with regard to control of the disease. The present tuberculosis eradication program in cattle involves testing and necropsy of selected individuals to confirm herd disease status. Infected herds are subjected to complete epidemiologic investigation in order to determine other herds having epidemiologic linkages to the index herd. Most infected herds are found by tracing tuberculosis-exposed animals to new herds, where they are evaluated for the presence of disease.

Figure 2

Elk traceback, 1990–91



Possible source herds, adjacent herds, and other contact herds are also investigated in this process.

Without authorities or indemnity funds, it is virtually impossible to conduct such investigations effectively. In some cases, it is not possible to determine a herd's status because owners will not willingly sacrifice the animals necessary for confirming disease through necropsy without compensation.

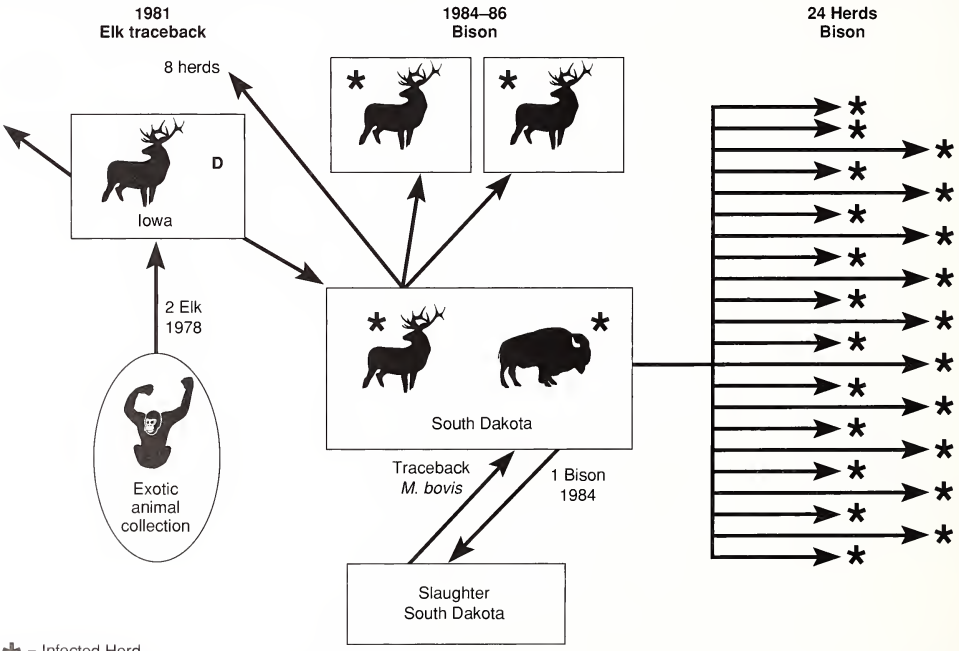
The serious consequence of this situation is that animals moving from such herds cannot be traced and evaluated for disease until tuberculosis has been confirmed in their herd of origin. The net result is that the situation currently existing in the United States today is essentially unmanageable.

Needs

Two needs vie for first priority for the effective management of the current tuberculous situation in Cervidae: (1) Federal statutory authorities must be examined to determine the degree to which cervid movements can be regulated with particular regard to the interstate movement of tuberculosis-infected and exposed animals. Minimum standards based on regulations are needed nationwide for quarantine, testing, and followup procedures, and for recognizing tuberculosis accredited-free herds for cervids. (2) A source of funds must be established to compensate owners for animals that must be destroyed because of tuberculosis. Without these funds, roadblocks will materialize at every avenue pursued toward controlling this disease. Many herds will not have accurate, timely evaluations for the presence of *M. bovis*. Infected herds will be missed for lack of sufficient testing and/or sampling, leaving the owner of infected herds free to market

Figure 3

Elk and bison traceback, 1981 and 1984–86



tuberculosis infected and exposed animals as "disease free." Traces requiring immediate action to ward off the introduction of disease to new herds will not be completed or will be inordinately delayed. Measures to avoid disease detection will become increasingly prevalent as self-preservation becomes the leading objective of owners and livestock dealers. Finally, herds in which *M. bovis* infection has been confirmed will remain infected because few owners can afford to sacrifice animals in the numbers needed to free herds of infection. Some owners, however, will voluntarily depopulate entire herds at any cost after observing the pathology characteristic of bovine tuberculosis in cervids.

In my opinion, only one option is open to the cervid industry. The elimination of bovine tuberculosis must be undertaken at any cost. It has become clear that the disease has invaded the cervid population sufficiently to preclude any other option. Half-measures will eventually lead to the same end as no measures, i.e., the termination of the captive cervid industry, and will adversely affect the cattle, bison, and swine industries as well. Most unthinkable is the potential for bovine tuberculosis to become established in wildlife—in deer and elk in our national parks and on Bureau of Land Management and Forest Service lands that provide summer grazing for our most enduring breeding cattle herds.

Summary

Bovine tuberculosis in captive Cervidae became an important issue in the United States during 1991. Following the report from Canada of possible disease introduction from the United States, investigations in FY 1991 led to the discovery of 10 infected cervid herds located in 8 States and 2 herds in which confirmation of tuberculosis is still pending. Investigations also showed the major significance of tuberculosis in captive cervids in the epidemiology of the disease in cattle and bison. Tuberculous elk discovered in 1981 were responsible for a 1984 outbreak of *M. bovis* infection in a bison herd which spread to a total of 24 bison herds located in 10 States and brought bison officially into the tuberculosis eradication program. Tuberculosis in two Nebraska cattle herds found to be infected or exposed in 1991 was attributed to contact with tuberculous cervids. Cattle and/or bison are present on at least four premises with tuberculous cervids. At present, the Federal Government has no provisions for restricting cervid movements and no tuberculosis eradication or control program for cervids. The Government also provides no compensation to owners for animals destroyed because of tuberculosis. This situation has resulted in major impediments to investigations and herd evaluations, making ineffective the efforts of animal health agencies to control the disease. The disease may already be so widespread that the only remaining option for saving the captive cervid industry is the elimination of tuberculosis at any cost.

Pathogenesis of *Mycobacterium bovis* Infection

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Introduction

Outbreaks of tuberculosis have been reported to occur in captive farmed Cervidae in the United States and other countries, although the disease has been nearly eradicated from domestic animals and people (Philip 1989, Tesaro et al. 1990, Stuart et al. 1988, Kollias et al. 1982, Towar et al. 1965, Carter et al. 1986, Clifton–Hadley and Wilesmith 1991, and Thoen et al., in press). Failure to eliminate tuberculosis in elk and deer maintained on farms or in animal parks or zoos is of concern to animal health regulatory officials because tuberculous animals may serve as foci of infection for wild animals, cattle, other domestic animals, and humans (Francis 1958, Thoen and Himes 1981, Sawa et al. 1974).

The diagnosis of tuberculosis in farmed Cervidae and other captive wild animals often is based on the results of delayed type hypersensitivity to tuberculins (Thoen 1988, Thoen et al. 1984). Purified protein derivative tuberculins (PPD's) prepared from *Mycobacterium bovis* or *M. avium* are widely used. Lymphocyte blastogenic assays (LBA) and other in vitro procedures have been described for detecting Cervidae exposed to virulent mycobacteria (Temple et al. 1979, Griffin and Cross 1989). Recently, enzyme-linked immunosorbent assays (ELISA's) have been reported for detecting antimycobacterial antibodies in sera of Cervidae and certain exotic species exposed to clinically significant mycobacteria (Thoen et al. 1980). The use of purified antigen preparations extracted from virulent strains of *M. bovis* using deoxycholate or potassium chloride provides for improved specificity in ELISA (Hall and Thoen 1986). A presumptive diagnosis of tuberculosis can be made on gross and microscopic examination of tissue specimens collected at necropsy; however, to confirm the diagnosis, it is necessary to isolate and identify the acid-fast organism (Thoen 1990).

Pathogenesis

Signs exhibited by tuberculous animals depend upon the extent and location of lesions. Only in advanced stages of disease are clinical signs, such as loss of weight and coughing, observed (Clifton–Hadley and Wilesmith 1991, Francis 1958). Enlarged superficial lymph nodes provide a useful diagnostic sign; however, lesions located in deep lymph nodes are of little or no value in establishing a clinical diagnosis. The general signs are weakness, anorexia, dyspnea, emaciation, and low-grade fluctuating fever. In *M. bovis* infections in mammals, the organs of the thoracic cavity and lymph nodes of the head usually are involved. When lungs are extensively involved, there may be an intermittent, hacking cough. The principal sign of tuberculosis commonly is chronic wasting or emaciation that occurs in advanced stages of disease despite good nutrition and care.

Cervidae are exposed to tubercle bacilli by aerosolization or by ingestion of contaminated feed or water (de Lisle et al. 1983, Thoen and Himes 1986). Following aerosol exposure, the organism is carried to the small air passages, where it is ingested by phagocytes. The phagocytes pass through the lining of the bronchioles, enter the circulation, and are carried to lymph nodes, parenchyma of lungs, or other sites. After ingestion of the bacillus, the now mononuclear macrophages attempt to kill the organism; however, virulent tubercle bacilli possess the ability to resist killing. Oxygen radicals released following ingestion, effective in killing other bacteria, appear to have little or no effect on tubercle bacilli. When the tubercle bacilli are ingested by the phagocytes into the phagosomes or intracytoplasmic vacuoles, the organism is protected from soluble factors in serum (fig. 1).

Following ingestion of the bacilli, lysosomes attach to each phagosome and the phagocytes attempt to destroy the bacilli. The hydrolytic enzymes present and released into the phagosomes fail to kill the bacteria. Therefore, the tubercle bacilli multiply and destroy the phagocytes. Other phagocytes enter the area and ingest tubercle bacilli. A small cluster of cells referred to as a granuloma develops. Cellular responses attempting to control the disease result in the accumulation of large numbers of phagocytes and finally the formation of a macroscopic lesion referred to as a tubercle. Microscopic examination reveals the presence of epithelioid cells and multinucleated giant cells (Thoen et al., in press). Acid-fast bacilli may be present in the lesion.

Detection of Immune Responses

The most reliable and practical method of reaching a tentative diagnosis in large, captive wild animals is to apply a single cervical tuberculin skin test. Animals infected with tubercle bacilli respond to proteins contained in tuberculin and develop characteristic delayed-type hypersensitivity reactions when tuberculoproteins are injected in the skin (Thoen 1988). If tuberculin is deposited in the deep layers of skin (intradermally), a local response characterized by inflammation and swelling is usually observed at 48 to 78 h in infected animals, whereas noninfected animals fail to develop such reactions at the injection site.

Cervidae infected with *M. bovis* react to tuberculin prepared from a culture filtrate of *M. bovis*. When testing for avian tuberculosis, the practitioner must use an *M. avium* tuberculin because animals infected with *M. avium* react less or fail to react to tuberculin prepared from the mammalian tubercle bacilli. The hair on the cervical site should be clipped or shaved. The dosage used in an intradermal tuberculin test is 0.1 mL (0.1 mg protein) of a suitable tuberculin.

Nearly all countries are currently using a strain of *M. bovis* for the preparation of mammalian tuberculin for veterinary use. Heat concentrated synthetic-medium old tuberculin

(HCSM-OT) was used in the past, but most countries (including the U.S.A.) are now using a purified protein derivative (PPD) tuberculin (Angus 1992). The PPD tuberculins are preferable because they are easier to standardize and more specific than HCSM-OT. Moreover, biologically balanced *M. bovis* and *M. avium* PPD tuberculins are particularly useful in conducting simultaneous comparative-cervical tuberculin tests (CCT) used to differentiate responses caused by mammalian tubercle bacilli and those induced by other mycobacteria. The CCT in Cervidae is performed by injecting *M. avium* and *M. bovis* PPD tuberculins into separate sites in skin of the neck within 10 days following the single cervical test. The difference in size of the two resultant responses usually indicates whether tuberculin sensitivity in a herd is caused by infection with *M. bovis* rather than *M. avium* complex, *M. paratuberculosis*, or a transient sensitization from saprophytic mycobacteria (e.g., *M. terrae* or other saprophytes) in the environment. These are some of the organisms isolated from animals that may induce false-positive reactions to tuberculin. The CCT should not be used in populations where *M. bovis* has been diagnosed.

New diagnostic tests for detecting immune responses have been reported; however, their efficacy has not been determined for use in the diagnosis of tuberculosis or other mycobacterial infections in Cervidae or other captive wild animals. A gamma interferon test has been utilized in detecting cattle with advanced tuberculosis lesions (Wood et al. 1990). A blood test for tuberculosis has been used on deer and elk in New Zealand (Griffin and Cross 1989). These in vitro tests require viable cells; practical use depends on reproducibility of results and cost of conducting the test.

Recently, investigations have been made on elk exposed to *M. bovis* in North America (Thoen et al. in press). Single cervical tuberculin skin tests were conducted by intradermal injection of 0.1 mL of *M. bovis* PPD in the midcervical region. The injection sites were palpated at 72 h for the presence of swelling. Animals with palpable responses were classified as reactors. The CCT was conducted 9 days following the single cervical test using biologically balanced PPD of *M. bovis* and *M. avium* injected at separate sites on the opposite side of the neck. The skin thickness was measured and recorded. Of the 28 elk responding to the single cervical test, 24 had greater responses to *M. bovis* PPD than to *M. avium* PPD on CCT. A biopsy was obtained of an injection site for microscopic examination. Numerous mononuclear cells and a few polymorphonuclear leukocytes were observed in the section. Edema was apparent. Necropsies were conducted on each of nine elk responding to the single cervical and comparative cervical tests. Extensive grossly visible lesions were observed in the pulmonary parenchyma of one elk. The microscopic appearance of the lesions revealed the presence of granulomas with only minimal fibrosis. A comparison of results of the single cervical test, CCT, LBA, and ELISA in elk in a herd in which *M. bovis* was diagnosed revealed that of nine elk positive on the single cervical test, eight were reactors on CCT, seven were positive on LBA using *M. bovis* antigen, and eight were positive on ELISA using a sarkosyl extract (SK-1) of *M. bovis*. *M. bovis* was isolated from one animal positive on each of the four tests. Necropsies have not been conducted on 19 reactors to the single cervical test. Six elk negative to that test were also negative on CCT and LBA; one such animal was positive on ELISA using *M. bovis* antigen. ELISA's were conducted on sera of nine tuberculin test-positive elk from a herd in Colorado in which *M. bovis* was diagnosed. The ELISA reactions using *M. bovis* antigen ranged from 0.58 to 1.76 with a mean value of 1.42. The ELISA reactions using *M. avium* antigen ranged from 0.27 to 0.98 with a mean value of 0.81. ELISA reactions greater than 1.0 were detected in sera of seven of nine elk tested. The results of ELISA conducted on sera of nine tuberculin-test reactor elk (seven with tuberculous lesions on necropsy) indicate that greater ELISA reactions were obtained using *M. bovis* antigens (*M. bovis* PPD and SK-1 of *M. bovis)* than were obtained using *M. avium* antigens. The ELISA reactions (mean value) using SK-1 of *M. bovis* were greater than the reactions obtained

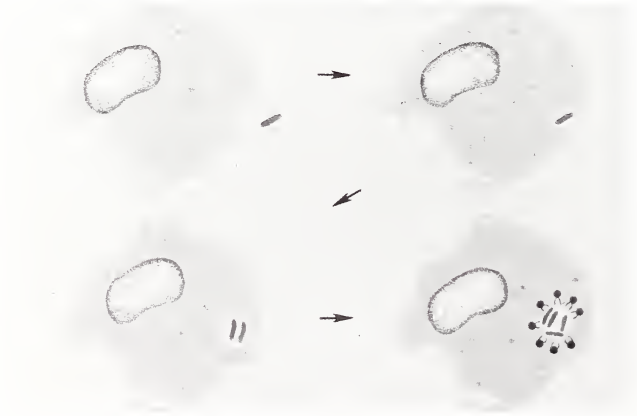

Figure 1— Schematic diagram of ingestion of tubercle bacillus by host phagocyte

using *M. bovis* PPD in sera of tuberculous animals; however, no important differences were detected in sera of controls.

Gene probes have been developed for detecting *M. tuberculosis* complex and for *M. avium* complex (Thoen 1990). Available information indicates that probes fail to differentiate *M. tuberculosis* and *M. bovis*; therefore, such probes have limited application in veterinary diagnostic laboratories because certain captive wild animals may be infected with either organism.

Discussion

Cervidae and other captive wild animals acquired for addition to a herd, animal park, or zoo collection should come from populations with a history free of tuberculosis. The period of quarantine should be a minimum of 3 months and preferably 4 months. During quarantine, prospective additions should receive a tuberculin skin test conducted in the cervical region. ELISA should be conducted on serum collected at 60-day intervals. Only tuberculin test-negative caretakers should be permitted to care for animals. Annual retests should be conducted to ascertain the caretakers' status.

When tuberculosis is diagnosed in an animal population, it is necessary to tuberculin-test all exposed animals. Tuberculin skin tests can be conducted at 3-month intervals. It is important to use a tuberculin prepared for veterinary use. Products prepared for human use are not of suitable potency for animals. When tuberculosis is diagnosed in a herd, it is necessary to remove tuberculin-positive animals from the population. In such an instance, the facilities, including feeders and watering containers, should be thoroughly cleaned and decontaminated using a cresylic compound or a derivative of phenol such as sodium orthophenyphenate. If possible, the premises should be disinfected two times at 14-day intervals. Halides, hypochlorite, and benzalkonium chloride, which are commonly used disinfectants, are not suitable for killing tubercle bacilli.

Investigations are needed to validate tuberculin test procedures for detecting tuberculosis in several species of captive wild animals. It is necessary in some captive wild species to determine the optimal dosage of tuberculin, appropriate test site, and most efficacious time for observing skin-test responses. The importance of immunosuppression following certain viral infections should be investigated (Thoen and Waite 1990).

The difficulty of replacing valuable bloodlines in Cervidae and other captive wild animals makes accurate diagnosis of tuberculosis very important. A serum bank has been established at Iowa State University for captive wild species for use in evaluating serologic tests. The development of DNA probes, the use of monoclonal antibodies and specific antigens in ELISA, and advances in genetic engineering techniques such as restriction endonuclease analysis may provide for improved testing methods for use in early and rapid diagnosis of mycobacterial infections (Labidi and Thoen 1989, Wood et al. 1990, Kuchinka et al. 1990, Thoen 1990). Stringent measures must be initiated immediately when tuberculosis is diagnosed to protect wild animals from infection.

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Clinical Aspects of Bovine Tuberculosis in Cervidae With Comments on the New Zealand Herd Accreditation Scheme

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Deer are *not* native to New Zealand; they were introduced approximately 100 years ago. Because there were no native predators and because the bushlands are extensive in New Zealand, the introduced deer thrived and their populations soared.

Mycobacterium bovis was believed to have been introduced over 100 years ago (in cattle from Australia). The rushtail possum was introduced 80 to 100 years ago. In the 1960's, there were some unexplained "breakdowns" with tuberculosis found in herds presumed "clean." In 1970, the significance of tuberculosis in New Zealand's possums was realized. Table 1 gives a historical overview of important dates and events in New Zealand's battle against tuberculosis in deer.

There are endemic areas of *M. bovis*-infected possums in isolated pockets in New Zealand. The country's present tuberculosis control scheme has undergone much modification during the late 1980's. It is now a practical working scheme. The individual incidence of deer infected with *M. bovis* has declined dramatically in the national herd, and the number of herds accredited free of tuberculosis has increased significantly. All this has been achieved despite a continuing problem with feral possums infected with tuberculosis and in the presence of a blossoming industry.

The primary test used to determine the presence of *M. bovis* in herds is the midcervical test. Despite its only having a sensitivity of 85 percent, it is very accurate in showing that a herd is infected. The midcervical test does, however, miss individual animals infected with *M. bovis* (false negatives).

Because of their specific habitats, social interactions, and uniqueness of the species' reaction to tuberculin, deer are very prone to react falsely to the cervical skin test. They contact mycobacteria other than *M. bovis* in the environment and then cross-react when given the skin test.

This problem led to the use of supplementary or secondary tests to check initial reactions to the skin test.

Table 1—Chronology of New Zealand's battle against tuberculosis in deer

1945	Voluntary dairy cattle tuberculosis control
1961	Compulsory dairy cattle tuberculosis control
1969	Deer farming starts
1969–85	Much live capture of deer
1971	Compulsory beef cattle tuberculosis control
1978	First case of farmed deer with tuberculosis
	Tuberculosis testing of problem deer farms
1979	Caudal-fold test discarded in deer. Skin testing begins.
1980's	Voluntary tuberculosis scheme for deer
1985	Use of comparative-cervical test introduced
1991	Compulsory tuberculosis scheme for deer and possum control plans

Performing postmortem examinations on a set number of reactors can avoid the destruction of all reactors in the instance where a high percentage of false-positive reactions are found in a herd of unknown history. (See table 2.)

When conducted correctly, postmortem examination has a relatively good sensitivity and is always useful, combined with other tests, in determining the presence of *M. bovis*. The CCT gives a lower sensitivity than the standard cervical test, and it is not advisable to use the CCT as an auxiliary test in a herd where *M. bovis* has been diagnosed.

The enzyme-linked immunosorbent assay (ELISA) is a useful test (and economical to use) across the whole herd. It is less liable to pick up early *M. bovis* infections but can detect late gross infections in animals that sometimes show a negative response to the skin test due to anergy.

The BTB gives us better information than skin testing on the tuberculosis status of individual animals.

In New Zealand, a herd is accredited tuberculosis free when it has achieved 3 clear whole-herd tests in a 2-year period. Every deer over 6 months old is tested. A test is not deemed clear until any reactors have been found disease free by the appropriate secondary test.

Where the previous testing history is unknown, a number of reactors may be slaughtered and postmortems may be performed on them, possibly with culture of pooled lymph nodes if there are no visible lesions.

To maintain a herd's accreditation, managers must follow certain rules. For example, deer newly introduced into the herd must have a certain tested status. All stock of breeding age also undergo a biannual test, and any stock slaughtered are monitored by veterinarians in deer slaughter plants. In areas where *M. bovis* is endemic in possums, breeding-age stock are tested annually.

If *M. bovis* is suspected, a "movement control" is instigated on the farm involved. A program of testing and slaughter is begun once the presence of *M. bovis* has been confirmed. Quarantine is lifted off the farm only when 2 clear whole-herd tests, 6 months apart, have been completed.

Any breakdown in accredited herds is treated very seriously, with extensive tracebacks and epidemiologic investigations. The restriction endonuclease analysis on *M. bovis* organisms involved in the outbreak may be used to give more information on the geographic origin of the strain of *M. bovis* involved.

The current protocol for deer being exported from New Zealand to Canada makes use of the history derived from the tuberculosis accreditation program. First, deer cannot be exported to Canada if there has been evidence of *M. bovis* in any animal on the property of origin during the 10 years preceding the date of commencement of testing for export to Canada.

The property of origin must be in the tuberculosis surveillance area, and no part of the property can be located

Table 2—Probability that one deer of a number examined postmortem will have tubercular lesions

Number of reactors	Number of necropsies	Herd prevalence of *M. bovis* 0.5%	1.0%	2.0%	4.0%	8.0%
3	3	0.98	1.0	1.0	1.0	1.0
4	3	.86	.97	1.0	1.0	1.0
5	3	.81	.93	.98	1.0	1.0
6	3	.78	.91	.97	.99	.99
7	3	.76	.89	.96	.98	.99
8	3	.75	.88	.95	.97	.98
9	3	.74	.87	.94	.97	.98
10	3	.74	.87	.94	.97	.98
15	3	.72	.85	.92	.96	.97
20	3	.71	.84	.92	.95	.97
4	4	1.0	1.0	1.0	1.0	1.0
5	4	.96	1.0	1.0	1.0	1.0
6	4	.92	.98	1.0	1.0	1.0
7	4	.89	.97	.99	1.0	1.0
8	4	.88	.96	.99	.99	1.0
9	4	.86	.95	.99	.99	.99
10	4	.86	.95	.98	.99	.99
15	4	.83	.93	.97	.99	.99
20	4	.82	.92	.97	.98	.99
30	4	.81	.91	.96	.98	.99
50	4	.80	.90	.96	.98	.98
5	5	1.0	1.0	1.0	1.0	1.0
6	5	.99	1.0	1.0	1.0	1.0
7	5	.97	1.0	1.0	1.0	1.0
8	5	.95	.99	1.0	1.0	1.0
9	5	.94	.99	.99	1.0	1.0
10	5	.93	.98	.99	1.0	1.0
15	5	.90	.97	.99	.99	.99
20	5	.89	.96	.99	.99	.99
30	5	.88	.96	.98	.99	.99
50	5	.87	.95	.98	.99	.99

Source: Proceedings of a deer course for veterinarians (no. 3). 1986. Rotorua, NZ: Deer Branch of the New Zealand Veterinary Association: 54.

within 16 km of any Tuberculosis Special Control Zone or movement-controlled herd.

The herds of origin of deer for export to Canada have

- Been fully accredited free of tuberculosis *(M. bovis)* for at least 2 years prior to the onfarm isolation of the animals for export to Canada.
- Had no additions of deer except from other herds accredited during the 12 months preceding the commencement of isolation of the animals for export to Canada. These herds supplying additions were at least 16 km away from any Special Control Zone.
- Been subjected to a whole-herd test of all animals within 8 months of the date of export (with negative results according to the New Zealand Deer Tuberculosis Control Scheme). This whole-herd test has to have been done at least 90 days after any previous tuberculosis testing so as to avoid any loss of sensitivity.

The individual animals destined for Canada must have been included in the whole-herd test and subjected to a skin test that turned out negative. Any animals in the export group showing an increase in skin thickness (reaction) must be slaughtered and given a postmortem examination. All applicable lymph nodes must be cultured for *M. bovis* or *M. tuberculosis.* All the negative animals are moved to an approved quarantine facility within 72 hours to wait for the maximum 120-day period needed to clear the reactors by negative culture. This facility must be a bird-proof, possum-proof, lockable building.

While in quarantine in Canada, the deer are subjected to a skin test for tuberculosis. Any animals showing a nonspecific reaction will be given the comparative cervical test at least 60 days after the initial test.

To qualify for shipment to the United states, the deer must have been resident in Canada for at least 60 days once they are Canadian citizens. During that time, they are subjected to another skin test, which must be negative.

The clinical picture of deer with tuberculosis can be varied. Generally, deer will not show much sign of infection until just prior to death. At that stage, they are usually wasting and may have visible abscesses that can suppurate to the exterior. The postmortem examination can reveal extensive lesions.

Many deer will "wall off" lesions after infection, and these may stay dormant for up to several years. Deer infected, under management stress, or stressed by the rut or normal lactation can develop generalized tuberculosis and succumb if the walled-off lesions break down.

Infection in many herds will not be diagnosed until a traceback from a known infected herd occurs. Such a situation occurred in Alberta in 1991.

I believe that the future of deer farming in North America depends heavily on the establishment of a tuberculosis control scheme. Here are some points worth considering:

- Is whole-herd depopulation, with today's current testing technology, warranted in a climate with no compensation?

- Is banning importation of deer from countries with a good tuberculosis testing history and strict protocols warranted when doing so could impede the development of an industry that could provide a viable, profitable alternative to some other wavering agricultural industries?

- Is controversy over the use of tests such as the BTB warranted? Even if the sensitivity is shown to be lower in North America than its performance in New Zealand? The BTB still gives us more information about an individual reactor and a herd than the mid-cervical test.

- Is the wastage of research material warranted in the whole-herd depopulations in Canada, where validation of tuberculosis testing could be done?

The mandate for this meeting must be to come up with some urgent actions. These are the points we need to address:

1. Some rules for within-State sales of animals.

2. Ways for a farm with tuberculosis-infected or reactor animals to get out of quarantine.

3. Ways for State veterinarians to be trained as soon as possible in tuberculosis testing for deer.

4. Rules for interstate movements of deer.

New Testing Procedures for Diagnosis of Tuberculosis in Cervidae

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The Disease

Since 1978, when tuberculosis was first diagnosed in New Zealand farmed deer, it has remained the most intractable of diseases involving farmed animals. It was not until l989 that a comprehensive, compulsory control scheme was introduced in New Zealand for the control and eradication of tuberculosis from captive Cervidae.

Some deer herds appear to be particularly susceptible to infection by *M. bovis*, the causative agent for tuberculosis in many species of ruminants. The disease may spread quickly if not diagnosed early and managed effectively, but under most circumstances *M. bovis* is a chronic, slow-growing organism with a slow rate of replication. The persistence of a feral reservoir of tuberculosis within New Zealand presents continued risk of reintroducing tuberculosis into disease-free herds of deer. Susceptibility to disease may be increased by environmental stressors, so tuberculosis can spread faster and be more severe in farmed deer than in wild deer. Furthermore, deer appear to be uniquely susceptible to sensitization by other species of mycobacteria. That phenomenon complicates the diagnosis of tuberculosis because of false reactions to tuberculin, which contains many common antigens shared by mycobacteria.

Deer may be exposed to tuberculosis infection by ingestion of bacteria through the oral route or exposure by respiratory inhalation. Should *M. bovis* persist within the host and undergo replication, a primary infection will establish itself within the lungs or the gut. The natural response of an infected host is to mount an immunologic reaction to ward off and eliminate the infecting organisms. Should this effort be unsuccessful, bacteria may spread from the primary site to draining lymph nodes within the affected area. Replication of bacteria within infected lymph nodes sets up a persistent cellular reaction that results in liquefactive, caseous or calcified lesions which are evident on postmortem examination of an infected carcass. Breakdown of lesions at primary sites or from infected lymph nodes may occur when animals are exposed to climatic or management stress. Severe spread of tuberculosis is most likely to occur under poor management conditions. Disease in animals may vary from barely visible, pinhead-sized lesions to large abscesses found within the lungs, gut, or lymphatic tissues.

There is considerable variation in the presentation of lesions in different deer herds. Animals in some herds may show lesions occurring predominantly in the nasopharyngeal lymph nodes, lungs, or thorax; those is other herds show lesions in the gut and mesenteric area.

Patterns of spread within herds can also be highly variable. Some herds may show rapid spread of tuberculosis over a relatively short time period (less than 3 months) while other herds may harbor small numbers of diseased animals that remain in the herd without undue spread to noninfected animals. Recent experience at our laboratory suggests that when tuberculosis is present at a significant level within a herd and remains undiagnosed for 3–5 years, a breakout of infection will occur with significant disease spread to young, susceptible animals. The problem is compounded somewhat by the difficulty of diagnosing disease in very young animals that show low-grade, atypical responses to tuberculosis within the first 6 months of life.

Tuberculosis Diagnosis in Captive Cervidae

Classically, infectious disease may be diagnosed by direct isolation of the infective organism from an affected individual. While this approach has been widely used in human medicine to diagnose infection, it has limited value for diagnosing many of the diseases found in veterinary species. In both brucellosis and tuberculosis in ruminants, it has proven extremely difficult to isolate the infective organism. Because these infections occur intracellularly, indirect techniques must be used to diagnose such diseases. Typically, immunodiagnostic techniques are used to diagnose disease where isolation of the organism is difficult. This principle relies on the fact that individuals exposed to an infectious agent will mount a specific immune response which can be taken as indirect evidence that infection has occurred. Such immune reactions may develop through a cell-mediated immune pathway or by the production of antibodies found in serum and mucosal secretions. Measurement of cell-mediated immune reactivity to tuberculosis using the classic skin test reaction has been used widely for diagnosing tuberculosis in animal and human medicine throughout most of this century. Though many different antigens have been used, purified protein derivative (PPD) remains the most effective antigen for tuberculosis diagnosis. The skin test has remained largely unchanged with the exception of minor refinements in the purification of mycobacterial antigens used for the test. A traditional test-and-slaughter policy has been used to identify and remove all animals deemed positive to a skin test. Whereas this technique is relatively cheap and easy to apply, it has limited sensitivity (70–80 percent) to diagnose infection and restricted specificity to exclude all noninfected animals accurately. Ideally, an immunologic technique should have 100-percent sensitivity and specificity to identify all infected animals and salvage all noninfected stock. Skin testing in deer appears more challenging than in cattle because of the technical difficulties in applying the skin test and the unique cross reactions found in deer following exposure to a range of nonspecific mycobacterial species. Rapid spread of disease to produce generalized tuberculosis in certain animals has meant that skin-test

nonreactivity (anergy) has been a persistent problem in implementation of skin testing for tuberculosis control in deer.

Though expensive, the skin-test-and-slaughter policy has been acceptable in cattle in a number of countries. It has been proven inadequate for tuberculosis management in farmed deer because of limitations in the sensitivity and specificity of the test system. Because tuberculosis is present at a relatively low incidence (<1 percent) the vast majority of reactions occurring following skin test with *M. bovis* tuberculin (PPD) are due to nonspecific sensitization with nondisease-producing mycobacteria. The validity of the test to identify infection is thus impaired, and large numbers of noninfected animals are wasted in a test-and-slaughter program. A further confounding complication is that, where tuberculosis is present within a herd, the test may fail to identify all infected animals to ensure eradication of disease from the affected farm. Producer resistance in the early stages of the skin-testing program for tuberculosis in farmed deer seriously limited the success of the program. Producers readily realized that the discovery of skin-test-positive animals constituted a significant liability. They were forced to slaughter large number of noninfected animals while running the risk of retaining test-negative but diseased animals in an infected herd.

Nonetheless, skin testing remains the most robust and widely applicable herd screening system for diagnosing tuberculosis. Should all skin-test-positive animals be considered at risk, the system can identify infected herds and contribute in a major way to disease control nationally. Such an approach, however, demands that ancillary tests be available to further evaluate skin-test-positive animals to establish the likelihood of disease or identify nonspecific reactivity caused by atypical mycobacteria. Animals reacting positively to the skin test should be considered an asset in a disease management program as they represent the most valuable group of animals that should allow for the accurate diagnosis or exclusion of *M. bovis* from the herd. If examined comprehensively, this select group of animals can provide important background information with which to define herd management strategies to facilitate disease diagnosis and eradication.

Ancillary Tests for Tuberculosis Diagnosis in Skin-Test-Positive Animals—The Comparative Cervical Test

Ideally, an ancillary test for tuberculosis diagnosis should retain the high sensitivity of the initial screen test and also increase the specificity of the test to exclude nondiseased reactors. A modified form of skin test using double inoculations of *M. bovis* PPD and *M. avium* PPD has traditionally been used as an ancillary test for tuberculosis management in cattle herds. This test, called the comparative-cervical test (CCT), has also been evaluated in deer but has been found to have serious limitations because of high levels of variability in the performance of the test in different operators' hands and under different farm conditions.

While the specificity of this test is >98 percent and it has an important role in identifying nonspecific sensitization following the standard skin test, the CCT has severe limitations when used in *M. bovis*-infected herds or where the status of the herd is unknown. Sensitivity varying from 30 to 80 percent has been attributed to this test for tuberculosis diagnosis in deer under farm conditions. This means that if disease is present at a low incidence within a given herd and nonspecific sensitization is present concurrently, there is a significant risk that the CCT may fail to identify small numbers of *M. bovis*-infected animals. New Zealand recommends that the CCT should not be used in herds with unknown history or where *M. bovis* has been diagnosed. These strictures limit the use of this test to herds with an exclusive history of nonspecific sensitization due to *M. avium* or other nonspecific mycobacteria.

Laboratory Tests for Tuberculosis Diagnosis—The New Zealand Blood Test

In the past 20 years, investigators have learned a great deal about the cellular and humoral immune mechanisms involved in the tuberculosis response. Our laboratory has developed a composite blood test for tuberculosis (BTB) that has added a new dimension to the more accurate diagnosis of tuberculosis in farmed deer. The BTB allows for the diagnosis of tuberculosis with a high level of sensitivity for disease identification and good specificity for the exclusion of nondiseased animals. The BTB involves critical measurement of cell-mediated immunity by culturing washed lymphocytes from blood samples in the laboratory using a variety of antigens obtained from *M. bovis, M. avium,* and nonspecific mycobacteria. Relative responsiveness to *M. bovis* and other mycobacterial antigens allows for specific diagnosis of disease using quantitative measures of cellular immune reactivity. In addition, the BTB measures antibody production (ELISA) in animals following exposure to *M. bovis* or nonspecific mycobacteria. Antibody levels appear to be particularly valuable in deer, which tend to produce a more florid and active antibody response to mycobacterial antigens. Measurement of inflammatory cofactors (ICF) in blood serum is also carried out to provide a third measure of host response to disease.

The BTB has been critically evaluated in almost 1,000 New Zealand deer herds, where reactions ranging from high levels of *M. bovis* infection, low levels of *M.bovis* infection, mixed levels of *M. bovis* infection and *M. avium* sensitization, and *M. avium* sensitization alone have been critically examined. Necropsy findings from more than 3,000 animals have been evaluated retrospectively to provide a critical data base to produce diagnostic parameters for cellular immunity, antibody, and inflammatory proteins as diagnostic aids for tuberculosis in deer.

Detailed analysis of findings from herds of mixed disease status and geographic location have produced test parameters for the BTB that incorporate all three laboratory measures of reactivity and produce a diagnostic test system with a sensitivity of >95 percent and a specificity of >97 percent for tuberculosis diagnosis and exclusion. By using the BTB in combination with skin testing, investigators have obtained significantly increased gains in accurate diagnosis of disease and salvage of noninfected stock.

The particular attributes of the different components of the BTB allow a composite test, using a variety of different antigens on a single blood sample to obtain a precise assay for tuberculosis management in deer. The data given in table 1 show that the lymphocyte transformation test alone provides a precise and specific probe for *M. bovis*-specific immune reactivity typical of deer infected with tuberculosis. Because the assay can be accurately quantified and there is a direct relationship between the level of reactivity and the severity of disease, the BTB can be used not only to identify the presence of disease but also to predict its severity. In addition, the test appears to be able to identify disease-specific immune reactivity to *M. bovis* significantly earlier than can be achieved using skin test reactivity alone. Furthermore, unlike skin testing (which requires a 90-day interval between tests to obviate posttest suppressive effects), lymphocyte transformation tests can be carried out within 10 days of skin testing and still provide an accurate measure of cellular immunity in the test animal. This means that combined skin testing and blood testing can be carried out over a relatively short time interval to improve the precision of tuberculosis diagnosis. Information can be accumulated rapidly to allow appropriate disease management strategies to be applied, to diagnosis or exclude tuberculosis.

The ELISA test, using antibody specifically directed against classes of deer immunoglobulin (IgG), has proven itself a particularly powerful tool in screening skin-test-negative animals where skin test anergy is considered in animals with serious tuberculosis that fail to react to conventional skin test. A special attribute of antibody testing (ELISA) is that it provides a powerful probe for the identification of animals with serious disease, the group most likely to become anergic to skin testing (fig. 1).

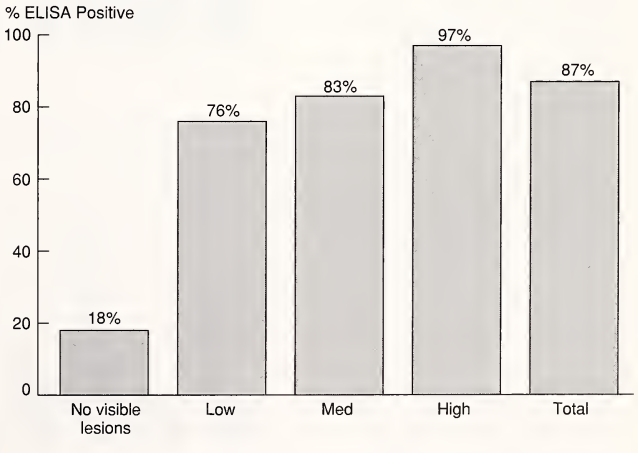
The results given in figure 2 show that the precision of ELISA is influenced not only by the quality of antigen used in the assay but also by the quality of the antibody conjugate used to detect the primary deer antibody specific for tuberculosis. In figure 2, it can be seen that when specific anti-IgG is used, the ELISA is more precise in diagnosing disease where 100 percent (4/4) of infected* animals (No. 1–4) are identified. Animals 5–9 are not infected. When polyclonal anti-IgG is used, the assay detects 75 percent (3/4) of infected animals. But when anti-IgM is used, the assay shows nonspecific *(M. avium)* reactivity in all animals, including the four *M. bovis*-infected animals. Generally, IgM is associated with cross-reactive low-affinity responses, which can obscure *M. bovis*-specific IgG antibody unless ELISA is carried out critically. When ELISA results are combined with lymphocyte transformation findings, a precise range of test markers is available. These markers allow for the accurate identification of disease ranging from early infection to seriously spreading, generalized tuberculosis. The combined tests improve the sensitivity obtained by

Table 1—Precision of lymphocyte transformation (LT) and comparative-cervical skin test (CCT) in diagnosing tuberculosis

	LT	CCT
Sensitivity	33/35 (94%)	18/28 (65%)
Specificity	49/54 (91%)	36/56 (64%)

Figure 1

Diagnosis of the presence and severity of tuberculosis *(M. bovis)* in deer using the ELISA

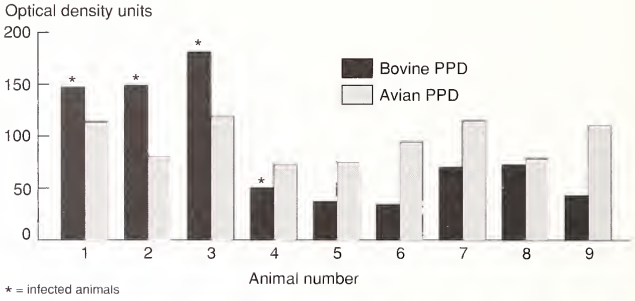


skin testing (84 percent, improved to >95 percent with BTB) and add a new level of specificity to accurately exclude nondiseased animals sensitized by other mycobacteria (table 2). Lymphocyte transformation and ELISA allow for the precise identification of reactivity uniquely directed against *M. bovis* while responses due to *M. avium* typically produce specific lymphocyte transformation reactivity and the consistent absence of mycobacterial antibodies in the ELISA test. The third component of the BTB, which involves the measure of inflammatory cofactors (haptoglobin), has been shown to be particularly important in confirming severe disease in animals with generalized tuberculosis. Inflammatory parameters are consistently elevated in animals with *M. bovis* infection. Specific sensitization to *M. bovis* PPD following skin testing causes a rapid increase in the level of inflammatory proteins circulating in the blood. Thus the inflammatory measurements taken 10 days after skin testing, the time when blood samples are routinely taken from skin-test-positive animals, provides an extra probe for disease reactivity in tuberculosis-infected deer.

The ability to carry out a multiple array of tests on a single blood sample allows for a multivariate analysis of reactivity in animals considered at risk from tuberculosis. Tests can be carried out repeatedly without any interference so that it is possible to monitor disease progress. Apart from using multifaceted tests, the ability to carry out a single test repeatedly offers a new level of precision for tuberculosis diagnosis in this species. The BTB test can be used to accurately identify herds with skin-test reactivity solely due to nonspecific sensitization with total salvage of all reactors. In addition, the system can be used to identify small numbers of diseased animals among a larger group of animals exhibiting nonspecific skin-test reactions. BTB or ELISA alone can also be used on skin-test-negative animals to identify skin-test "anergic" animals where disease is known to persist in the face of repeated cycles

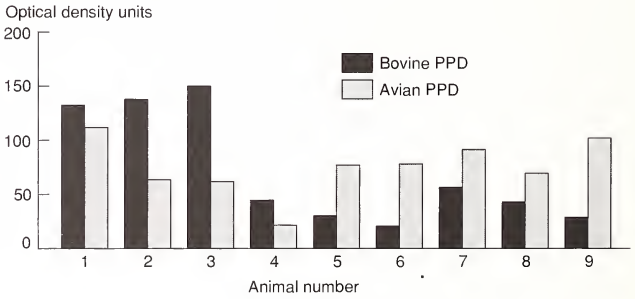
Figure 2

Total antibody titers to bovine and avian PPD found in deer exposed to *M. bovis*



* = infected animals

IgG antibody to bovine and avian PPD in sera from deer exposed to *M. bovis*



IgM antibody titer to bovine and avian PPD in sera from deer exposed to *M. bovis*

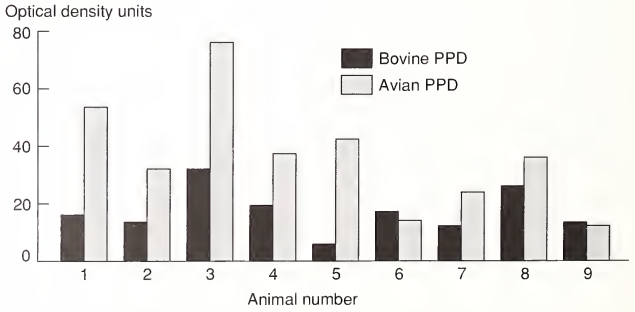


Table 2—Relative performance of the blood test for tuberculosis (BTB) and skin testing (ST) in diagnosing tuberculosis

	Sensitivity	Specificity
BTB	158/166 (94%)	420/446 (91.6%)
ST	139/166 (84.2%)	365/446 (82.3%)

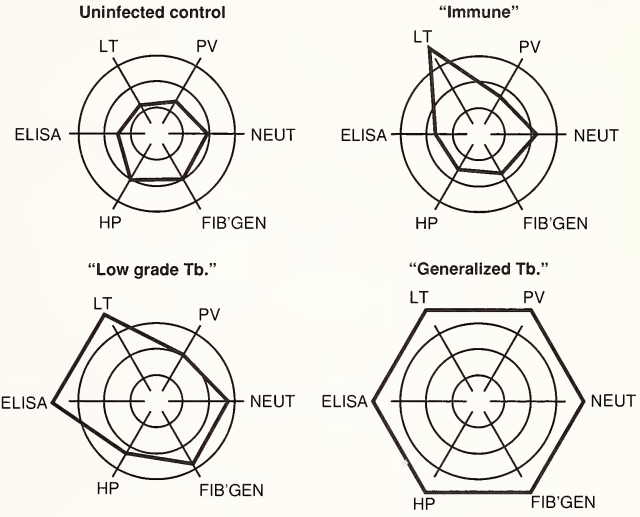
of skin testing. Data given in table 2 show how a low incidence of anergic animals can be detected among larger groups of skin-test-negative animals when the testing veterinarian suspects false-negative skin-test reactions.

Obviously the complete BTB—being a comprehensive test—is expensive for widespread use, so in most situations, ELISA alone is used to screen larger numbers of skin-test-negative animals where false-negative reactions to the skin test are suspected.

Together, the new generation techniques, combined with traditional skin testing, provide a new concept for tuberculosis diagnosis and exclusion for a newly farmed species such as deer. Because each parameter provides a quantitative measurement of disease-related reactivity, when combined, the two produce a more precise diagnostic statement. That, in turn, allows predictions to be made about the type, severity, and incidence of disease. This technology has been recognized internationally and has been used to diagnose and manage tuberculosis in exotic animals such as Arabian oryx, gazelle, ibex, and nilgar. The technology is in use in Europe, the United States, and the Arabian peninsula and has been shown to be transferable to species other than deer where tuberculosis produces significant management losses in collections of exotic animals. While the relevance of parameters such as lymphocyte reactivity and ELISA varies between species, depending on their patterns of reactivity to tuberculosis, the overall relevance of each parameter remains for all species so far tested.

Figure 3

Radial plot showing levels of inflammation [neutrophils (Neut), fibrinogen (FIB'GEN), haptoglobin (HP), plasma viscosity (PV)], antibody (ELISA), and lymphocyte transformation (LT) in diseased, immune, and noninfected deer. The inner circle represents two standard deviations (sd) below the mean value for the species. The outer circle represents two sd above the mean with the mean being represented by the circle that lies between these two limits.



The challenges posed by tuberculosis management in farmed New Zealand deer have promoted new approaches to tuberculosis diagnosis that are now seen as relevant in other species of wildlife. Thus a further facet of information gained in the management of New Zealand deer is the provision of new technology for disease diagnosis that may be applicable over many species of wildlife now being subjected to more intensive management practices.

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Mycobacterium bovis Infection in Humans Exposed to Elk

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Index Animal Case

In April 1990, a young veterinarian was asked to see an elk noted to be failing. This was 1 of a herd of 200 animals on 1 of the 109 registered elk farms in Alberta. A retropharyngeal abscess was treated with streptomycin injections for 1 week, with no improvement. Over the next 6 weeks, 2 drainage procedures were carried out, and penicillin and sodium iodide for suspect actinomycosis were administered. In July, the lesion had extended to the cervical area. Excision was attempted but failed, and the animal was euthanized. At postmortem, tuberculosis was suspected on the basis of extensive caseating and purulent lesions of cervical and thoracic nodes, lungs, liver, spleen, and mesenteric nodes. However, it was not until *Mycobacterium bovis* was isolated in November 1990 that Tuberculosis Services, Alberta Health, was notified.

Contact Followup

The farm owner and family skin-tested negative for tuberculosis. The veterinarian and his assistant reacted positively to 5 tuberculin units of purified protein derivative (PPD). According to standard contact followup (fig. 1), a chest x-ray and sputum cultures were undertaken. Both people were symptom free and had normal x-rays. Sputum from the veterinarian (one of three specimens submitted in December 1990) yielded a mycobacterial growth (January 8, 1991). Although full identification was not available until March 1991, treatment was initiated with three drugs, isoniazid (INH), rifampin, and pyrazinamide.

By March 1991, details of the wider animal investigation raised concern for others persons exposed. Of 69 herds quarantined, 32 had reactors and 7 had culture-positive animals. Federal agents carried out field testing, and provincial agents performed laboratory investigations. Two large herds were disposed of through a single rendering plant.

All agencies involved were notified of the potential risk, and their personnel were asked to self-identify their degree of exposure and be tested at their local health units.

As of July 8, 1991, 412 persons had reported exposure and 359 had been assessed. Skin testing was negative in 285. Thirty-one had a history of previous positive tests, and 43 were positive for the first time. Table 1 summarizes these statistics.

Tuberculosis in Alberta

Rates of human tuberculosis in Alberta are low—6.4 per 100,000 population in 1990 (fig. 2). Rates are highest in the elderly and in aboriginal (40 per 100,000) and foreign born people (20 per 100,000). Control activities, managed provincially, consist of passive case-finding, active contact followup, and surveillance programs in aboriginal school children, in hospital and extended care centers, and in correctional institutions. Bacillus Calmette Guérin (BCG) vaccine is

Figure 1

Followup testing for people contacted by elk tuberculosis in Alberta, 1990

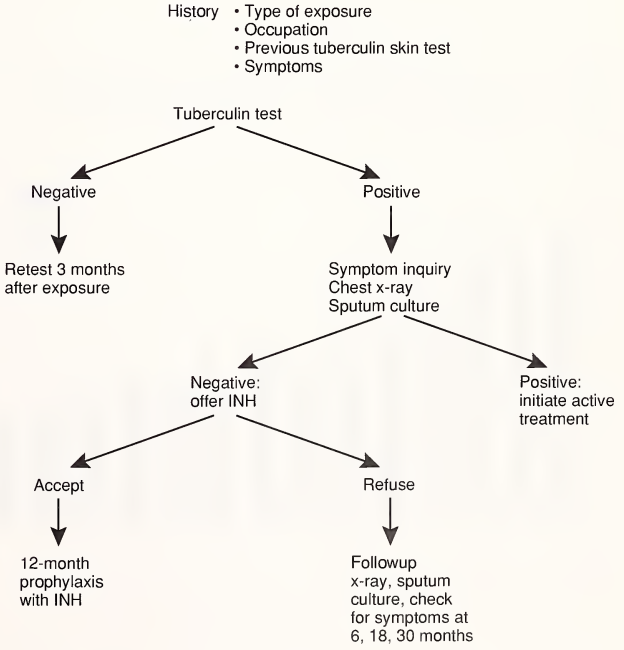


Table 1—Human contact to elk tuberculosis (through July 8, 1991) following exposure in Alberta Province in 1990

Number of people listed	412	
Number assessed	359	
Results (first test)		
Tuberculin negative	285	(2)
Previous positive	31	(8)
New positive	43	(11)
Number not yet assessed	53	
Number taking a 2d test	62	
Negative	57	
New positive	3	
Pending	2	

Numbers in parentheses represent those who have a record of BCG vaccination, which may be responsible for the positive result.

administered to aboriginal children at birth.

The infection prevalence in Albertans is not known but is estimated at 10 percent. Hence, the reactor rate in contacts of elk of 74:359 (21 percent) appeared high.

The highest reactor rates were found among those dealing with herds having culture-positive animals. Of 168 tested, 16 (10 percent) were previously positive and 32 (21 percent) were newly positive (table 2).

Second testing in negative reactors began shortly before this symposium. To date, five converters have been identified (5:64 or 8 percent).

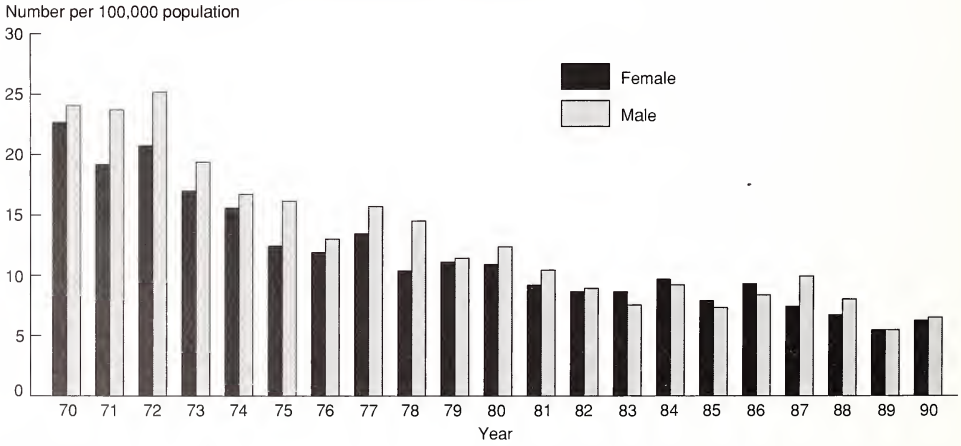
In the first test, 8 of 29 veterinarians (29 percent) dealing with the reactor herd were reactors, whereas none of 14 dealing with nonreactor herds were positive. The reactor rate at the rendering plant was 18 percent.

Farmers' reactor rates were low; laboratory workers, higher; and tanners, highest (22:33 or 66 percent) (table 3). Among tanning workers, most were born outside of Canada (Portugal and Vietnam), where tuberculosis rates are significantly higher than in Canada.

Of significance was the skin test conversion of two rendering plant workers on second testing (table 4). One was an animal skinner and the second, a foreman.

Figure 2

Cases of tuberculosis in humans in Alberta, by year, 1970–90



May 6, 1991

Table 2—Type of contacts exposed to elk tuberculosis in Alberta, 1990, recorded as of July 8, 1991

	Nonreactor herds	Reactor herds	Culture-positive herds	Unknown or No contact	Total
First test					
Number	107	64	168	73	412
Previously positive	11 (4)	2 (1)	16 (2)	2	31 (8)
Newly positive	4 (3)	5 (2)	32 (4)	2 (2)	43 (11)
Negative	78 (1)	54	107	46 (1)	285 (2)
Not tested	14	3	13	23	53
INH recommended or accepted	0/0	2/0	27/19	1/1	30/20
Second test					
Number	11	14	37	2	64
Negative	11	14	32	2	59
Positive (conversion)	0	0	5	0	5
INH recommended or accepted	0	0	4/4	0	4/4
Reactor rate					
Pct. previously positive	10	3	10	3	8
Pct. newly positive	4	8	21	3	11
Pct. conversion	0	0	14	0	8

Numbers in parentheses represent those who have a record of BCG vaccination, which may be responsible for the positive result.

Recommendation for Reactors

It was recommended to all reactors that they undergo medical assessment, including chest x-ray, symptom inquiry, and sputum culture (table 5). Where assessment is complete, 8 require no further followup, 28 have been recommended INH prophylaxis, and 20 have accepted. Eight will be followed at 6, 18, and 30 months. Except for the index veterinarian, none had positive cultures.

M. bovis as a Zoonotic Infection

Frequency

M. bovis is rarely reported in people in the western world. In Alberta, 1982–89, there were 1,493 isolates of *M. tuberculosis* and 1 of *M. bovis* reported. In 1979, the U.S. Centers for Disease Control (Atlanta, GA) reported 16,582 *M. tuberculosis* infections isolated in people and 11 *M. bovis* infections isolated. A report from southeastern England found that 4.5 percent of isolates from 1977–84 were *M. bovis* and all were in persons born outside of England.

In 1983 in Peru, 4.45 percent and in Argentina, 4.1 percent of isolates were *M. bovis*. Before prepasteurization (about 1920), *M. bovis* accounted for 5 percent of the tuberculosis in the United Kingdom.

Method of Spread

Although there has been an assumption that *M. bovis* is invariably transmitted by ingestion of infected milk, evidence for aerosol dissemination is clear. Abattoir workers in southern Australia were found to have a reactor rate of 54 percent when 1 case led to a wider investigation. Of five people testing positive for tuberculosis, four had lung lesions and one had renal tuberculosis due to *M. bovis*.

Table 3—Occupations of people contacted by elk tuberculosis in Alberta Province, 1990 (first test)

Occupation	Nonreactor herd			Reactor herd			Culture-positive herd		
	#	pp	np	#	pp	np	#	pp	np
Federal veterinarian or inspector	9	0	0	10	1 (1)	0	5	0	2
Private veterinarian	5	0	0	9	0	1	5	0	4
Rendering plant worker or inspector							72	5 (1)	9 (1)
Farmer	69	8 (3)	1	38	1	4 (2)	41	0	1
Laboratory personnel	11	0	1 (1)	5	0	0	16	2 (1)	3 (1)
Tanner							33	9 (1)	13 (2)
Other or unknown	15	1	0						
Total	109	9 (3)	2 (1)	62	2 (1)	5 (2)	172	16 (3)	32 (4)

= number, pp = the number of reactors who had previously tested positive for tuberculosis, and np = the number who were newly identified as positive for tuberculosis. Numbers in parentheses represent those who have a record of BCG vaccination, which may be responsible for the positive result.

Site of Disease

M. tuberculosis is almost invariably spread by aerosolized droplets from the cough of a person with a large, productive pulmonary lesion. The primary infection goes undetected except for tuberculin conversion as immunity develops. Adult-reactivated tuberculosis is predominantly a pulmonary disease (80 percent), but lesions may involve any organ system: lymph nodes, kidney, bone, central nervous system.

Although some reports indicate that *M. bovis* in people is more likely to cause extrapulmonary lesions (Ontario 58 percent, southeastern England 60 percent), in Australian abattoir workers, 90 percent had pulmonary disease.

Summary

1. *M. bovis* is pathogenic for people.

2. Although *M. bovis* may be spread by ingestion of infected, unpasteurized milk, the most common efficient mode of spread is by aerosolization of the organism.

3. People in the following job classifications are especially at risk for contracting *M. bovis* infections: handlers and caretakers of sick animals, rendering plant workers, and laboratory workers involved with postmortem examinations of animals.

4. Screening and regular followup of workers are essential until the disease is eradicated.

5. The organism is sensitive to INH, rifampin, and ethambutol, but **not** pyrazinamide.

6. INH prophylaxis is appropriate for those infected but showing no disease symptoms. Although INH has been shown to be 80 percent protective against reactivation of *M. tuberculosis*, it has not been proven protective in *M. bovis* disease.

Table 4—Contact outcome by occupation of people contacted by elk tuberculosis in Alberta Province, 1990 (second test), as of July 8, 1991

Occupation	Nonreactor herd		Reactor herd		Culture-positive herd	
	#	*Converter*	#	*Converter*	#	*Converter*
Federal veterinarian or inspector	9	0	4	0	3	1
Private veterinarian	0	0	4	0	0	0
Rendering plant worker or inspector	0	0	0	0	20	3
Farmer	0	0	3	0	11	0
Laboratory personnel	3	0	4	0	5	1
Tanner	0	0	0	0	0	0
Other or unknown	0	0	0	0	0	0
Total	12	0	15	0	39	5

= number, and converter = a person whose tuberculin test was first nonreactive but on second test became reactive.

Table 5—Investigation of human reactors to elk tuberculosis in Alberta Province, 1990, as of July 8, 1991

Number	First test, newly positive	Previously positive	Conversion
Active case	1	0	0
INH recommended or accepted	19/15	5/1	4/4
Following 6, 18, 30 months	4	4	0
Culture pending	2	1	1
Being evaluated	20	18	0
No followup necessary	1	7	0

Bovine Tuberculosis in Cervidae: the History, Current Status, and Accreditation Program in Britain

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History

Before 1980, bovine tuberculosis in British deer had been reported only from zoos (Jones et al. 1976). Surveys of wild deer had shown a high incidence of avian tuberculosis but no bovine tuberculosis (Matthews et al. 1981).

However, in November 1980, a wild roe deer shot in the southwest of England, an area known to have bovine tuberculosis in its wild badger population, was found to have generalized bovine tuberculosis. A second infected roe deer was shot in the same area in 1984. Surveys of wild deer were, therefore, conducted in this area. Of 450 wild deer examined at necropsy, 7 were found to have infection (Ministry of Agriculture, Fisheries and Food 1989). Further extensive surveys of wild deer in the United Kingdom, particularly among the 350,000 or so wild red deer in the Scottish Highlands, are still continuing but have revealed no further cases of bovine tuberculosis (Ranald Munro and Hugh Reid, pers. commun.) However, as the early work had shown, avian tuberculosis is extremely widespread and is actually recoverable by culture from 30 percent of wild red deer in Scotland (Hugh Reid, pers. commun.).

This was the situation prior to 1985, when three batches of red and fallow deer were imported into Britain from Hungary. Each batch was found to have animals with generalized tuberculosis, and all animals were slaughtered. Of those 106 deer, 19 had visible lesions and 26 cultured positively (Stuart et al. 1988).

A second recorded outbreak, in January 1988, involved deer imported from Hungary and West Germany, but in this case the herd had been totally dispersed to 11 farms. Movement restrictions were placed on these herds, and tuberculosis was subsequently confirmed on five farms. All herds on those five premises were eventually totally destroyed (Philip 1989).

Testing Procedures

Using data collected from these outbreaks, the Ministry of Agriculture considered various testing options. Immediate attention focused on the comparative cervical skin test. Published reports from New Zealand indicated that the standard or single skin test was effective in deer in that country when carried out carefully and under good conditions (Wilson 1986). But there the level of *M. avium* reactivity is evidently low. Because of very high reactivity at the avian site and the known high incidence of *M. avium* in Britain, the Ministry adopted the comparative skin test.

Evidence from New Zealand also indicated that testing at short intervals was associated with reduced skin reactivity (Carter et al. 1984, 1985). Therefore, the Ministry adopted a very long intertest interval of 120 days.

When the results from the repeated skin tests of deer following the initial outbreaks in Britain were correlated with necropsy results and culture results, it was concluded that two levels of interpretation were needed. First, a "normal interpretation" based on herds presumed healthy and in which no infection had been found. This interpretation coincides with that used in cattle herds known to be infected. In the "normal interpretation," a positive reaction (at either site) is one in which the 72-hour skin thickness is 2 mm (or more) greater than at the time of first injection. The animal is deemed a reactor if there is a positive bovine and negative avian reaction or a positive bovine reaction more than 2 mm greater than a positive avian reaction. Test results are classified as inconclusive if there is a positive bovine and positive avian reaction but the difference in size between the two is less than 2 mm.

If a positive culture has been made from the herd and infection is therefore proven, then the "infected herd interpretation" must be used. In such herds, a positive reaction at either site is one where the 72-hour skin thickness is 0.5 mm or greater. The deer is classed as a reactor if there is a positive bovine reaction and a negative avian reaction, or if there is a positive bovine reaction equal to or larger then a positive avian reaction. Test results are declared inconclusive if there is a positive bovine reaction 0.5–2 mm less than the positive avian reaction (Griffiths 1990).

As might be expected, these interpretations have proved extremely difficult to apply in the field, and the technique for measurement is not devoid of observer error. In order to reduce this error and because of the difficulties of ensuring that veterinarians accustomed to testing cattle carry out the skin test in deer to the necessarily very high standard, a series of training courses funded by the practitioners attending has been organized by the specialist branch of the British Veterinary Association dealing with deer—the Veterinary Deer Society. Only veterinarians attending these courses can carry out the skin test in deer, and they are designated Local Veterinary Inspectors (Deer). It is recommended that a 1-mL hand syringe with fine-gauge needle be used on a site prepared to surgical standards and that the sites of injection be marked with a permanent-ink felt-nib pen.

If these tests are carried out correctly, the British Ministry of Agriculture claims that the use of these interpretations will give a test of 82-percent sensitivity and 70-percent specificity (Clifton–Hadley and Wilesmith 1991). It should be emphasized, however, that this rate of accuracy depends on observations made in herds where, in most cases, there was a high supposition of infection. The farmers and the Local Veterinary Inspectors (Deer) hope that these interpretations may be relaxed in the light of further test results.

Other Tests

Because of the unreliability of the skin test, research has been directed at developing further ancillary tests. In New Zealand, practitioners use a blood test (the BTB) that incorporates a lymphocyte stimulation assay originally developed to diagnose tuberculosis in humans who are skin-test negative (Verma et al. 1974, Steiner et al. 1980). The BTB has been strengthened by the measurement of other haematolytic variables and apparently has much greater sensitivity and specificity than the standard skin test (Griffin and Cross 1989). It has not, however, been adopted in Britain because it is too expensive and intricate. Instead, British research efforts have been concentrated on adapting the ELISA test, which employs monoclonal antibodies. This test has been found to have an extremely high level of specificity, but its sensitivity remains low, particularly in recently infected animals, which may not have produced antibodies against *M. bovis* to any great extent. The ELISA should, however, prove effective at detecting more advanced anergic cases (Swarz et al. 1983, Ministry of Agriculture, Fisheries and Food 1989). An ELISA test developed to give rapid assessment of tuberculosis status in badgers is also currently undergoing field trials. This test permits trapped badgers to be assessed in the trap, allowing animal control officials to make the decision on whether to euthanize the animal or release it onsite. Because it is an economical and relatively simple test suitable for screening, the ELISA has been incorporated into routine tuberculosis testing in the United Kingdom, and it is a requirement that all herds entering the Accreditation Scheme be subjected to a whole-herd ELISA.

Hope for an improved test also centers on the refinement of two tests developed in Australia for diagnosing *M. bovis* by detecting the gamma interferon released in whole blood after stimulation by *M. bovis*-specific antigen. The first of these tests is a bioassay that recognizes both deer and cattle gamma interferon (Wood et al. 1990). But this test is labor intensive, time consuming, and not specific for gamma interferon (Clifton–Hadley and Wilesmith 1991). The second test is a sandwich enzyme immunoassay currently being used in cattle in Australia. Unfortunately, this test does not pick up deer gamma interferon (Rothel et al. 1990). A research program has begun to develop this test for deer at the immunology department of Birmingham University Medical School in Britain. The Animal Diseases Research Association in Edinburgh, Scotland, is also involved in this work.

Legislation

In 1989, as a result of pressure from deer farmers, the British Ministry of Agriculture introduced an overdue package of measures to control subsequent outbreaks of bovine tuberculosis in deer. On June 1, 1989, the Tuberculosis Deer Order came into force requiring all cases of suspected tuberculosis to be referred to the veterinary authorities. The order also empowers the veterinary authorities to restrict movement of animals off the farm and allows the authorities to compel the whole herd to be skin-tested. It prohibits treatment or vaccination of deer. Most important of all, it requires deer farmers to mark all their deer individually and to keep movement records.

A further package of legislation introduced in September 1989 also provides for the payment of compensation at half the market value for any animals that the veterinary authorities require to be slaughtered.

The British Accreditation Scheme for Tuberculosis in Deer

In 1989, following the introduction of the above legislation to control tuberculosis outbreaks in deer, a voluntary Deer Health Scheme was established with the object of providing a nucleus of accredited herds. In brief, it requires a herd to skin-test clear three times using the "Normal Herd Interpretation" described earlier. Also, an ELISA must have been carried out at the time of the first test. Each skin test must be given a minimum of 120 days and a maximum of 6 months after the previous test. Calves are tested from 6 months of age on.

Because of the very high cost of testing—entirely (except for the ELISA) borne by the farmer—and especially because of the risks of false negatives and the cost of lengthy movement restrictions, only about 15 herds entered the Scheme in the first 12 months of operation.

Current Status

Following the tuberculosis outbreaks associated with imported deer, a large number of deer have been subjected to careful comparative skin testing and ELISA tests. This testing was undertaken to trace confirmed outbreaks, to enter new herds in the accreditation scheme, and also, most importantly, in connection with exports of deer breeding stock, particularly to France and Ireland. Probably around 20,000 deer have been tested. Only 18 animals tested positive for tuberculosis. A further 15 suspicious cases have arisen as a result of meat inspection and necropsy. Yet of these 33 suspected cases, only 11 have been confirmed.

It is quite clear, therefore, that the level of bovine tuberculosis in the British farmed deer herd is encouragingly low.

Table 1 documents the number of confirmed outbreaks of tuberculosis in British deer since 1985.

Contrary to expectations, it also appears that the quite heavily stocked commercial deer farms do not have much impact on the prevalence of the disease. Indeed, we now know that animals in several very lightly stocked deer parks established centuries ago harbor tuberculosis. In one of these parks, established 300 years ago, only 1 animal out of 460 culled has shown visible lesions or produced *M. bovis* from tissue culture.

Unlike the Danish situation, where bovine tuberculosis was eradicated many years ago, or New Zealand, where the growing numbers of possums create a changeable situation, Britain's tuberculosis predicament in deer appears relatively stable. We will continue to carry very low levels of tuberculosis in our badgers and, as we now know, in our wild and park deer. The disease rarely creates clinical signs, and evidence for spread to cattle from deer in Britain is so far nonexistent and from badgers, apparently very localized. Where we have extensive historical parks with a very low level of infection, handling the deer is impossible without very radical and unpopular moves. Because such parks will no longer be able to sell live deer and because all meat is inspected at slaughter, there is no likelihood of changing a disease scenario that has been in existence for centuries until we have an improved tuberculosis test available.

Our efforts, therefore, revolve around the establishment of accredited farmed deer herds and thorough monitoring of the wild and park deer population by meat inspection.

Table 1—Outbreaks of tuberculosis in deer in Britain since 1985

	Farmed deer	Wild deer
1985	3	7
1986	0	—
1987	0	0
1988	6	2
1989	4	3
1990	5	3
1991	2	—

Summary of Status

There is a very low level of bovine tuberculosis in English wild deer, probably no bovine tuberculosis in Scottish wild deer, and only very low levels of bovine tuberculosis in British farmed deer.

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Epidemiology of an Outbreak of Bovine Tuberculosis in Confined Elk Herds

Charles D. Stumpff, D.V.M.

Reports of tuberculosis infection in elk are rare in the United States. Existing reports document occasional incidents in elk living at zoos.

Reports of tuberculosis in other Cervidae are also few. One of the most complete reports was made in the March 1965 issue of the American Journal of Veterinary Research. There, Towar et al. report on tuberculosis in captive fallow deer.

The following case report will cover an outbreak of tuberculosis in captive elk herds located in North and South Dakota, including epidemiologic considerations.

History and Diagnosis

In November 1980, herd owner "O" purchased 42 bull elk from herd owner "H"; both are located in the State of South Dakota. These animals were placed in the same enclosure with approximately 20 other elk owned by "O." These elk were in approximately 320 acres of pasture surrounded by an 8-foot woven wire fence. Animals were fed hay and grain in cattle feeders. Water was provided in regular stock watering tanks. Essentially, the elk were cared for under conditions similar to cattle. No cattle had fenceline contact with this group of elk. However, there were cattle on adjoining farms. The elk were located in ranch country and maintained under ranch conditions.

Clinical Signs

The 60-odd elk exhibited few clinical signs of tuberculosis. Poor conditioning was the first indication of illness. Also, animals would lag behind the rest of the herd. Infected elk would eventually go down and die shortly thereafter, in spite of treatment. One animal had an abscess in its flank region. This abscess was drained but did not respond to treatment.

In January 1981, the first death loss occurred. Losses continued at 3- to 4-week intervals until 10 animals had died. Necropsies were performed on nine animals; eight showed suspicious lesions. Two of these were caused by *M. bovis* based on confirmation at the National Veterinary Services Laboratories (NVSL) on August 11 and 14, 1981.

The exact method of tuberculosis testing of many exotic animals is not fully understood. The method used for domestic cattle is often used in wildlife species. One such report of tuberculosis testing of captive fallow deer in Michigan (Towar et al. 1965) lists tests on many animals with apparently accurate results. Similar testing methods were used in this report of elk herds.

A cervical test was conducted on the remaining 53 animals. Thirty elk were classified as reactors; 23 were negative. Reactors were separated from the negative animals. The test consisted of applying to the cervical region 0.1 mL special PPD for cervical use. The site was midway in the neck in a clipped area prepared by a clipper using a #40 surgical blade. Skin thickness was measured prior to injection and at 72 hours after injection. Diameter size of the response was also measured. Animals showing any response were considered to be reactors. Application and interpretation of this test was made in accordance with USDA recommendations for tuberculosis testing in cattle. Similar procedures were used by Towar et al. in their report of tuberculosis in a captive deer herd.

Increases in skin thickness ranged from 1 to 27 mm. Diameter measurements of responses varied from 5 to 40 mm.

Pathology

The first animal involved had a large abscess in the flank region. This animal was restrained, and its abscess was treated. Complete healing never occurred. Of the nine animals examined at necropsy, eight exhibited lesions suspicious of tuberculosis. All animals had granulomatous lesions in the lung tissue with little or no lymph node involvement. At least one animal had two huge mesenteric node abscesses. *M. bovis* was isolated from two specimens submitted to NVSL. One elk died about a week after the testing procedure. That animal had gross lung lesions and mesenteric lymph node involvement. The results of histopathology suggested tuberculosis; however, attempts to culture bacteria were not successful. At the time of tuberculosis testing, the elk were also tested for brucellosis. Two elk were classified as reactors to that test.

Herd owner "H" is a dealer in native and exotic wild animals. He maintains a herd of buffalo, elk, and deer. When he became aware of the problem in O's herd, H arranged slaughter of five adult cows. One cow elk slaughtered had gross lesions of tuberculosis in the mediastinal lymph nodes. *M. bovis* was subsequently isolated from tissues submitted to NVSL. H's herd was tested like O's herd. Twenty tuberculosis reactors were disclosed. Fifteen other animals tested negative. One animal that was classified as a reactor had an extensive draining abscess on the right side in the rib region. Exudate material submitted to NVSL resulted in another *M. bovis* isolate. H believes that the infection probably entered his herd in the fall of 1978 from a purchase made at a zoo in Iowa. During the past 2 years, he has had unexplained death losses. The buffalo herd on the same premise was tested with negative results. When one herd of domestic cattle was also tested, one animal was classified as a tuberculosis suspect. When it was slaughtered, no gross lesions were observed. H's herd will remain under surveillance, and further testing will be completed. When H's animals were also tested for brucellosis, approximately 90 percent were classified as reactors.

In North Dakota, herd owner "J" purchased 17 elk from H in the summer of 1981. Five animals died of unexplained causes within 2 to 3 months. A test on this herd revealed 13 tuberculosis reactors of 15 tested. Test procedures were similar to those previously described. A necropsy was performed on one animal with a minute response. A single small gross lung lesion was observed. At this time

laboratory confirmation of tuberculosis has not been made.

In April 1979, North Dakota herd owner "L" purchased one bull calf from H. This animal, plus 13 others, was tested for tuberculosis in accordance with previously described procedures. All 14 animals tested negative. No clinical signs have been observed in this herd.

In the fall of 1979, herd owner "R" in South Dakota bought seven bull calves from H. Field investigation of R's herd indicated that the animals involved were immediately shipped to a Wyoming herd owned by "F." R maintains a privately owned animal exhibit that is open to the public. Elk at this exhibit have been tuberculosis-tested with negative results.

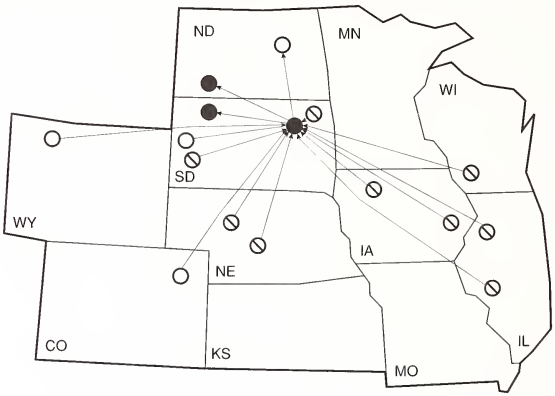
In northern Wyoming, herd owner F purchased bull elk sold by H to R. Owner F manages a ranch of 20,000 acres that is completely fenced to maintain elk. This ranch has approximately 150 elk and 400 cattle. Tuberculosis tests on both species were negative. Montana tested several elk herds that had received animals from F's ranch. All elk herds tested in Montana were negative.

Circumstantial evidence indicates that H's herd was the probable source of this tuberculosis outbreak. Effort was made to determine the source of infection in H's animals. Movements are illustrated in figure 1. Nine herds located in seven States were investigated. Several herds were tested and found to be negative. H had bought animals from many sources, including zoos. One theory with circumstantial support is that the infection entered H's herd from a zoo animal purchased in 1978. This animal died with apparent clinical signs of tuberculosis a few months later, but no effort was made to determine the cause of death. The source of infection in H's herd has not yet been determined.

Three persons associated with the South Dakota herds converted from negative to positive status on a tuberculosis test. Herd owner H, the attending veterinarian associated with O's herd, and a rendering plant worker were the people involved.

Figure 1

Location of elk herds in States involved in this outbreak



This outbreak in South Dakota resulted in extensive legal problems that still continue. O's herd was retested in August 1982; 46 reactors were destroyed, and 10 animals were classified as negative and will be subjected to retesting. H's herd was retested, and 30 of 31 animals were classified as reactors. All elk were destroyed. Five deer were tested; two were classified as reactors. All deer were destroyed. During the period of first and second testing, both herds continued to experience death losses of approximately 20 percent.

In North Dakota, J's herd experienced heavy death losses in the winter of 1981–82. Eight animals were destroyed in February 1982.

Conclusions

1. As the bovine tuberculosis program reaches its final conclusion, consideration must be given to handling of reservoirs of tuberculosis in exotic animal collections. Many are maintained in agricultural conditions and represent a potential source of tuberculosis to livestock populations.

2. In many instances, State and Federal regulations are not adequate to handle outbreaks of tuberculosis in wild animal collections properly.

3. All tuberculosis problems in animals present a public health hazard to humans. This incident reemphasizes the need for adequate safeguards in handling tuberculosis-infected animals.

4. There is a need for information in regard to tuberculosis testing techniques and methods of diagnosis of tuberculosis infection in exotic animals. This outbreak in elk presented an unusual opportunity to evaluate such procedures. This opportunity was lost due to absence of funds and supporting regulations.

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Epidemiology of Bovine Tuberculosis in Elk Herds—1981

Charles D. Stumpff, D.V.M.

This is a summary case report of an outbreak of bovine tuberculosis in captive elk herds located in South and North Dakota in 1981, including epidemiologic considerations. A more detailed report appeared in the proceedings of the United States Animal Health Association, 1982.

North and South Dakota experienced outbreaks of bovine tuberculosis in three herds in 1981. All herds were related, with one herd considered to be the source herd. Here are the highlights of the case report:

• Two of the three herds were confirmed to be infected by the isolation of *M. bovis*. One herd was considered to be infected due to association with the source herd, high mortality, and high response rate of animals tested.

• The single cervical test was used in all infected herds and exposed animals. Two confirmed herds had a response rate of 57 percent. Response sizes ranged from increases in double skin thickness of 1 mm to 27 mm. The other herd had a response rate of 86 percent.

• All three herds suffered from significant death loss. Losses ranged from 25 percent to 66 percent over a period of 18 months to 2 years.

• Only one herd had the advantage of veterinary diagnosis. This was the first herd confirmed. Postmortem examination in this herd revealed gross lesions of tuberculosis in eight of the nine animals examined. Tissues from two animals were confirmed as infected by *M. bovis*. The other two herds suffered death loss, but no attempt was made to determine the cause.

Table 1—Purchases and sales of elk and deer in South Dakota Herd "O," 1979–80

Animals bought	Animals sold
3 white-tailed deer Des Moines, IA February 1979	2 deer December 1980
3 yearling elk Medara, ND State Park	
Herd "H" South Dakota November 1979–January 1981	

• Losses were of a chronic nature, occurring at regular intervals, but large numbers of elk did not die at one time. For example, the source herd reported a loss of 25 animals over a 2-year period.

• Clinical signs were not spectacular. Animals were observed to be sick only a day or two before death. Emaciation was the most common symptom. Two animals had superficial abscesses that did not respond to treatment. *M. bovis* was subsequently isolated from one animal.

• Postmortem results reported by veterinarians listed lesions in lung tissues and lymph nodes.

• Elimination of bovine tuberculosis in all elk herds was not considered practical or possible due to many reasons, including but not limited to legal, economic, and technical considerations.

• All three herds were destroyed 6 months to 1 year after the diagnosis following extensive legal proceedings.

• Further tracing activities did not disclose other infected herds.

• No source herd was found for the animals infected in South Dakota. Circumstantial evidence indicates that the most likely source was one animal purchased in Iowa in 1978 from an exotic animal dealer.

• Buffalo tested by South Dakota personnel at three different times were negative; these were owned by the same man who owned the South Dakota source herd. In 1985, this buffalo herd plus another owned by the man's father were considered the source of the extensive buffalo episode.

Table 2—Purchases and sales of deer and elk in South Dakota Herd "H"

Animals bought from many sources	Animals sold to many purchasers
*3 Iowa 4 Wisconsin	North Dakota—1 infected herd, 1 negative herd
*2 Illinois 4 Nebraska	South Dakota—1 infected herd, 1 negative herd
4 South Dakota 1 North Dakota 1 Colorado	Wyoming—1 negative herd

* Zoo sources in these States were considered the most likely sources of infected animals. By the fall of 1978, no source had been positively identified, however.

• The caudal-fold test was used on a number of low-risk herds. No responses were reported.

• Serum samples were submitted to Dr. Charles Thoen at Iowa State University for enzyme-linked immunosorbent assay (ELISA) evaluation. There appeared to be close correlation between the results of the ELISA and those from skin testing.

• Complete evaluation of test procedures was hampered because postmortem examination of animals destroyed was not possible.

Several problem areas of significance were as follows:

1. Information on tuberculosis test procedures in elk were meager at best. In this case, the single cervical test appeared effective in identifying reactors within known infected herds. The caudal-fold test was used in one herd. In my experience, this site proves difficult to inject and interpret.

2. Insufficient regulatory authority. Either such authority (State and Federal) was absent or the existing State regulations were so general that they invited litigation. Federal regulatory procedures for tuberculosis in elk do not exist.

3. Lack of indemnity monies on both State and Federal sides. Some solution must be found in this area. Industry should be expected to share in the cost of this solution as well as its benefits.

4. Incomplete postmortem and diagnosis techniques can influence proper evaluation of testing procedures.

5. The threat of spread of infection to other species of animals, including people and domestic cattle.

History, Current Status, and Accreditation Program in Denmark for Bovine Tuberculosis in Cervidae

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Bovine Tuberculosis in Denmark: History and Current Status

Bovine tuberculosis was officially eradicated in Danish cattle in 1959. In May 1988, a fallow deer herd was found to be infected with tuberculosis. The herd, which comprised approximately 500 adult fallow deer, was thoroughly infected and was disposed of. During the autumn and winter of 1988–89, infected deer were found in 12 herds. The last infected deer was found in a herd in February 1991. Of the 14 herds with infected deer, 6 have been disposed of totally, 1 has been slaughtered by the owner, 2 have been declared free of tuberculosis after the test and slaughter procedure, and 5 are still under official supervision. Approximately 1,600 animals have been slaughtered in these infected herds. It is believed that the disease was imported with deer from Germany in 1986–88.

Danish Deer Statistics

According to the Danish law on deer farming, all enclosures with deer must be registered at the Veterinary Services. As of April 30, 1991, a total of 294 deer farms and 468 deer parks were registered.

In summer 1991, an estimated 25,000 adult fallow deer *(Dama dama)* and 3,000 adult red deer *(Cervus elaphus)* were kept in deer farms and deer parks. The figures do not include yearling bucks and stags for slaughter.

Accreditation Program

An official and compulsory accreditation program was launched in January 1989 and reevaluated in August 1990 (Regulation number 619 from the Veterinary Services). Basics of the accreditation program are:

- All deer 1 year old or older in deer farms and deer parks must be tested 3 times before December 31, 1991, with individual tests being at least 4 months apart.

- All deer must be tagged with the authorized, tamper-proof CKR-eartag before commencement of tuberculosis testing. The CKR-tagging system is based on a five-digit farm ID number and a four-digit animal number. Tags can be ordered only through the National Committee on Cattle Husbandry, where records of all orders are kept. The CKR-tag for deer is a round plastic tag, 22 mm in diameter, and, once inserted, must not be removed. If the tags are properly inserted, the loss rate is very low, probably less than 1 percent per year. Deer must be tagged with the CKR-tag no later than at weaning.

- The comparative cervical test (CCT) is used for testing.

- The CCT is translated as follows:
(1) Avian reaction only or avian reaction bigger than bovine reaction: Avian Reactor.

(2) Bovine reaction only, no bigger than 2 mm: Negative Reactor.

(3) Bovine reaction bigger than 2 mm: Positive Reactor.

- Antemortem and postmortem veterinary inspection is compulsory in all deer farms and in deer parks smaller than 50 ha.

- Movement restrictions exist. Deer can be moved only between herds with the same testing status or from higher to lower status. Animals must have been tested for tuberculosis within 4 months of being moved, and a special movement certificate must be issued by a veterinarian.

- Reactor animals or herds with tuberculosis-infected stock are dealt with specifically. All reactors are slaughtered, and farmers receive full compensation for each animal. Where reactors are found, herds are placed under immediate movement restrictions, and all trade partners are subjected to similar restrictions.

Autopsy, histology, microbiology, and culturing are carried out on material submitted from reactor animals. If no sign of tuberculosis is found, all restrictions are lifted.

If tuberculosis is diagnosed, the herd undergoes an intensified testing program, including tests of all animals every 4 months. Reactors are slaughtered, and material is submitted for laboratory investigation. Three clear whole-herd tests are required before lifting the movement restrictions is considered. In each specific case, thorough evaluations are carried out before a movement restriction is lifted.

- Upon written application, dispensation from the testing program can be given to deer parks only. The parks must either be "old Danish deer parks" (i.e., the Royal Park north of Copenhagen) or parks stocked solely with deer from these "old Danish deer parks." All deer shot or found dead in "dispensated deer parks" must undergo postmortem veterinary inspection. The veterinarian attached to the individual park must report annually to the Veterinary Services, stating number of deer inspected. "Dispensated deer parks" can sell breeding stock only upon fulfilling certain tuberculosis testing requirements, specified in each particular case.

- All costs incurred in the testing program are carried by the deer owner. In reactor herds, veterinary costs are carried by the Veterinary Services.

Compulsory Eradication Program Status

Per April 30, 1991, status of the eradication program is:

- 121 herds have achieved accredited status (3 clear whole-herd tests).

- 169 herds have accomplished 2 clear whole-herd tests.

- 192 herds have accomplished 1 clear whole-herd test.

• Thus a total of 482 herds are accredited or in the process of testing.

• 113 deer parks have obtained dispensation from the testing program.

In all then, 595 herds are accredited, in testing, or dispensated.

• 175 herds are pending in the system, either in the process of obtaining dispensation, voluntarily disposing of their deer herds, or facing legal prosecution for disobeying the law.

• Tuberculosis-infected deer have been found in 14 herds.

Investigations indicate that no transfer of tuberculosis has taken place from deer in deer farms or deer parks to other domestic livestock or to the feral deer population.

The compulsory eradication program is clearly well under way. Preliminary results indicate that tuberculosis has been reeradicated, or is very close to being so, in Denmark.

Important Experiences Gained During the First 2 Years of the Testing Program

1. Close and uniform cooperation between veterinary authorities, industry representatives, and personnel with experience in deer management and handling is a necessary basis for the successful implementation of a tuberculosis testing program in deer herds.

2. Immediate, thorough, and detailed registration of all enclosures with deer is essential.

3. Compulsory, authorized, and tamper-proof tagging is an essential part of any testing program.

4. Movement restrictions, combined with testing requirements for animals to be moved, are essential in limiting the spread of the disease.

5. Compensation for reactor animals is an important factor in the process of convincing deer farmers or park owners to fulfill any testing program.

6. Thorough understanding of the nature and biology of deer is essential in designing a tuberculosis testing program for deer because their annual cycles impose limitations on possible testing periods.

7. Management, yard-design, stockmanship, and confident handling are key points in fulfilling the testing program in the individual farm or deer park.

Conclusion

The outbreak of bovine tuberculosis in Denmark in May 1988 represented a reintroduction of the disease, where it had been eradicated since 1959, and imposed severe restrictions on the newly established deer farming industry. However, an immediate and combined effort to eradicate the problem was mounted by the Veterinary Services and supported by industry representatives. This effort has been a success in controlling the disease. Three years after the first confirmed case of tuberculosis in Danish deer, the disease is under full control and is probably already reeradicated in Denmark. Investigations indicate that the disease has not spread between deer herds, to other populations of livestock, or to the feral deer population.

Tuberculosis in Zoo Ungulates

Murray E. Fowler, D.V.M.

Introduction

In general, tuberculosis is thought to be a disease of humans and their domestic animals but with some spillover into captive wild animals and, more rarely, free-living wild animals. Tuberculosis has probably been a disease of zoo animals ever since captive collections were begun. The first recorded case occurred in a chimpanzee at the London Zoo in 1836 (Owen 1836). Thenceforth, the pathologist of the zoo periodically reported about tuberculosis. I have identified nearly 50 references to tuberculosis in captive wild ungulates without reviewing the literature prior to 1970.

Historically, certain groups of animals, namely primates and birds, were known to be highly susceptible, and many exhibits were designed to avoid direct contact by humans. Tuberculosis has always been present in ungulates, but it has received less emphasis than other infectious diseases.

The term "ungulate" derives from the Latin *ungula*, which means the "hoof." It may also refer to a talon or a claw. In zoo circles, members of the Orders Artiodactyla and Perissodactyla are considered ungulates even though some species have nails rather than hooves. Also, for this presentation, I am including elephants in order to cover all of the large herbivorous quadrupeds.

Nondomestic ungulates may be maintained in a variety of facilities other than a classic zoo, including zoological gardens and parks, wild animal or game parks, safari parks, wildlife safaris, game ranches and farms, menageries and circuses, roadside animal parks, children's zoos, deer parks, or private collections. Traffic between these institutions may have a bearing on the epidemiology of tuberculosis.

The American Association of Zoological Parks and Aquariums (AAZPA) has accredited 150 zoos. Each accredited zoo is required to have an approved veterinary medical program with provisions for clinical necropsy of dead animals. All zoos are regulated under the provisions of the Animal Welfare Act and are routinely inspected by officers of U.S. Department of Agriculture.

Numerous other institutions can maintain wild ungulates without regulatory control. Zoos accredited by the AAZPA are not allowed to sell surplus animals to other institutions or animal dealers that are not so accredited. Nor can such zoos sell animals to private individuals. A recent television expose demonstrated that there are loopholes in the acquisition and disposition process, however. For example, these rules do not exclude purchase from nonaccredited institutions.

Why be concerned about tuberculosis in zoo ungulates? Is there a problem? If so, who is responsible for solving it? Can the problem be solved with current technology, or must additional research be done to make it feasible to solve the problem? It is known that some North American zoos have had tuberculosis in their ungulate species. Some entire collections of the affected species have been depopulated. Mycobacteriosis is surely a challenge to some zoo veterinarians and the institutions that they work for. However, infection is not universal throughout the zoo world.

I have identified only 15 North American zoos that experienced tuberculosis (clinical or at necropsy) in their ungulates during the last 20 years. Some incidents involved a single animal; epizootics were handled by cooperative efforts of the zoo administration, zoo veterinarian, regulatory officials, and in some cases public health officials. A few situations remain unresolved.

Of important concern are those cases where nonspecific tuberculin reactions appear in closed groups in zoos where there has never been a history of *M. bovis* infection.

In 1976 an international conference on mycobacteriosis in zoo animals was held in Washington, DC. The proceedings of that meeting (Montali 1978) should be required reading for those responsible for the regulatory aspects of tuberculosis. Speakers described their experiences with ungulate tuberculosis and expressed concern about the unreliability of then-current testing procedures and the necessity of developing suitable testing for all interinstitutional movement of animals. What has been accomplished in the intervening 15 years?

Reasons for Prevalence of Tuberculosis in Zoo Ungulates

1. The chronicity of the disease in most species.
2. A long prodromal state, allowing spread of the agent before clinical signs appear.
3. Unreliability of diagnostic tests.
4. Survival of the organism in the enclosure.
5. Close quarters for zoo animals.
6. The stress of captivity.
7. The fact that tuberculosis has not been regulated in zoos.
8. Questionable quarantine procedures.

Mycobacterial Species of Concern

All of the species of mycobacteria reported in domestic animals have also been reported from zoo ungulates. The major concern is *Mycobacterium bovis,* but *M. tuberculosis* has also been isolated. The *M. avium* complex may be a primary pathogen or cause interference with tuberculin testing and other diagnostic tests.

M. pseudotuberculosis has been isolated from nondomestic sheep and goats, a few antelope species, and llamas. There may be numerous species of atypical or saprophytic mycobacteria that share common antigens sufficient to interfere with tuberculin testing.

Epidemiology

Numerous studies have been carried out in zoo epizootics, and apparently all the routes of infection known for domestic animals occur in zoo ungulates. The primary lesions are in the

lung (thus aerosolization is the primary source of the disease for other animals), but infection in the liver and intestinal tract or swallowing coughed-up sputum will contaminate feces. Kidney infections are reported, so urine may also be a source of infection. Congenital infection is rare, but it has been reported in at least one camel (Mason 1918).

It is difficult to trace the ultimate origin of infection in most zoo ungulates, but it is likely that initial infection occurs when zoo ungulates commingle with infected cattle or are housed in enclosures contaminated by cattle. Most *M. tuberculosis* infections arise from association with humans having an active infection.

The host range is broad. It is likely that most zoo ungulates could become infected with tuberculosis, given the right set of circumstances. Table 1 provides an overview of reports of tuberculosis in zoo ungulates, with no pretext of being an exhaustive list. The omission of a species from this list may simply reflect lack of exposure. However, it is worthy of note that certain groups are absent from the reports, namely, equids and hippopotami, while others, such as cervids and bovids, are frequently reported.

Table 1—Zoo ungulates found to have tuberculosis in the last 20 years[1]

Asian elephant	*Elephas maximus*
Perissodactyla	
Black rhinoceros	*Diceros bicornis*
Common tapir	*Tapirus terrestris*
Artiodactyla	
Peccary	*Tayassu tajacu*
Camelidae	
Dromedary	*Camelus dromedarius*
Bactrian	*Camelus bactrianus*
Llama	*Lama glama*
Guanaco	*Lama guanicoe*
Cervidae	Numerous species
Giraffidae	
Giraffe	*Giraffa camelopardalis*
Bovidae	
Wisent	*Bison bonasus*
Bison	*Bison bison*
Yak	*Bos grunniens*
Water buffalo	*Bubalus bubalis*
Cape buffalo	*Syncerus eaffer*
Sable antelope	*Hippotragus euinus*
Addax	*Addax nasomaculatus*
Greater kudu	*Tragelaphus strepicerso*
Eland	*Taurotragus oryx*
Beisa oryx	*Oryx gazella beisa*
Arabian oryx	*Oryx leucoryx*
Blackbuck	*Antelope cervicapra*
Sitatunga	*Tragelaphus spekei*
Impala	*Aepyceros melampus*
Gnu	*Connochaetes tauriuus*
Waterbuck	*Robus ellipsiprymnus*
Gazelle	*Gazella gazella*
Markhor	*Capra falconeri*

[1] This is not an exhaustive list but indicates the diversity of ungulates involved.

Clinical Signs

Most wild animals are adept at masking clinical signs until late in the course of any disease. The chronicity of tuberculosis increases the risk that long-term infection may go unnoticed by handlers.

Because tuberculosis can affect many organ systems, clinical signs may vary greatly among animals. One common sign is anorexia and accompanying weight loss; however, this is not universal. Weight loss may be masked in animals with heavy coats. In a giraffe, malnutrition may be severe enough to produce generalized serous atrophy of internal fat stores without marked muscle wasting.

Generalized pulmonary tuberculosis may produce dyspnea, coughing, and possibly a nasal exudate, but I have examined tuberculous animals having 90 percent of their lung parenchyma replaced by granulomas yet showing no dyspnea unless stressed. Exercise intolerance would be an important sign.

Animals with severe involvement of the thoracic cavity are poor risks for anesthesia and may die during any stressful event (dystocia, surgery, immobilization).

Pathology

In general, the lesions of tuberculosis in zoo ungulates mimic those observed in domestic animals. Every organ system may be involved. The lungs and liver are usually affected, but infection may be restricted to the thoracic or mesenteric lymph nodes. As in domestic animals, particular species of mycobacteria may attack only specific tissues or organs. Granulomas have been reported from the spleen, meninges, mammary gland, uterus, bone, epidermis, and lymph nodes.

Delayed hypersensitivity and the granulomatous response may vary slightly from species to species. Pathologists may find some cases difficult to interpret.

Diagnosis

As was said at the symposium 15 years ago, there is probably no single diagnostic test other than culture and speciation that is absolutely reliable

for diagnosing tuberculosis in zoo ungulates. All of the diagnostic tests employed with domestic animals have been tried on zoo ungulates. Intradermal tuberculin testing may or may not be useful.

The following tests have been employed for both diagnosis and surveillance:

1. Culture—Some species of mycobacteria are quite fastidious. All of them require long incubation periods.

2. Intradermal tuberculin testing—Both single and comparative cervical tuberculin tests have been used on a number of species of zoo ungulates; however, the caudal-fold location seems to be used most often. The eyelid has also been used. No definitive studies have been done on the suitability of the various tuberculins for specific animals. There is a major concern about the reliability of tuberculin testing in some groups of animals. It is known that equids, felids, and camelids may not produce a good delayed hypersensitivity reaction. False-negative reactions occur and may be explained on the basis of anergy, inappropriate concentration of the tuberculin for the species being tested, or immunodeficiency preventing the delayed hypersensitivity response (T-cell deficiency). Contrarily, false positives may result from sensitization with atypical or nonpathogenic antigens and an inflammatory rather than hypersensitivity response.

Of the 70 zoo veterinarians responding to Montali and Hirschel's 1990 survey on tuberculin testing of ungulates, 3 tested only suspects, 59 tested upon arrival, 50 tested on departure, 27 tested regularly, and 28 tested occasionally.

3. Enzyme-linked immunosorbent assay (ELISA).

4. Lymphocyte blastogenic assay (LBA), also called lymphocyte transformation.

5. Hemagglutination.

6. Ophthalmic sensitivity—A sensitizing dose is instilled into the conjunctival sac, and a confirming dose is administered 72 hours later.

7. Fecal culture.

8. Radiography.

9. Tracheal wash.

10. Submolecular biology, such as gene probes, etc.

Differential diagnosis must include any disease causing chronic wasting, such as dental disorders, parasitism, or neoplasia. Abscessation caused by numerous bacteria may not be identifiable on gross necropsy. Yersiniosis is more of a problem in nonhuman primates but is possible in ungulates. Ungulates maintained in facilities in the Southwestern United States may be at risk for coccidioidomycosis. Both tuberculosis and coccidioidomycosis produce granulomas and thus may not be differentiated on gross examination, but the spherules of coccidioides are easily identified on low-power microscopic examination.

Challenges

Zoo veterinarians and administrators attempting to manage tuberculosis in ungulates face several formidable challenges that have significant economic implications or may strain public relations: (1) prevention, (2) diagnosis, (3) surveillance, (4) public health, (5) quarantine, (6) treatment, and (7) depopulation.

Research Requirements

Solving the problem of tuberculosis in zoo ungulates is not impossible, but it will require more information than we now have. The following are my suggestions about the topics that researchers need to address.

1. Status of delayed hypersensitivity reaction in ungulate species.

2. Appropriateness of tuberculin testing and the proper site for conducting tests.

3. Alternate laboratory tests that are suitable for the various species (lymphocyte transformation, ELISA).

4. Pathogenesis of tuberculosis in ungulates. What is the time lag from first exposure to the organism and a positive reaction to tuberculin?

5. Development of a surveillance protocol suitable for intrazoo management and interzoo movement.

6. The part that animals that share an enclosure play in perpetuating an infection (rodents, opossums, raccoons). The European badger *(Meles meles)* in England and the brush-tailed possum *(Trichosurus vulpecula)* in New Zealand are intimately involved in the epizootiology of the disease in dairy cattle in their respective countries.

Conclusions

A number of zoos have had to deal with an epizootic of tuberculosis or have a continual endemic problem. The veterinarians in each situation had to face the issues as if such experiences were new or unique. This ought not to be true. Zoo animals are valuable, if not irreplaceable. Zoo veterinarians should be able to speak with confidence about tuberculosis, and I believe that, with the technology available today, some of the seven challenges listed earlier could be met if all parties concerned are committed.

Some conclusions reached following this meeting are as follows:

1. Testing procedures applicable to cattle and bison cannot be automatically applied to all zoo ungulates.

2. The time will not likely come when there are data available to statistically compare the various tuberculosis testing procedures on zoo ungulates. There simply are not large herds of

surplus animals that are available to use for test evaluation. It may be necessary to rely upon necropsy records and herd history to a greater extent.

3. Treatment options must be considered for animals that test positive but are genetically important. Genetically important individuals must not be automatically euthanized because of a single positive tuberculin response. To this end, research on appropriate therapeutic regimens should be undertaken.

4. Zoos and zoo veterinarians are willing to help supply funding and surplus animals for tuberculosis research.

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Captive Cervid Tuberculosis and Concerns of the State Veterinarian

Donald P. Ferlicka, D.V.M.
Montana State Veterinarian

Every State in the Union has a chief animal health official. To ascribe certain human qualities to this individual, the title State Veterinarian has been affectionately continued. The State Veterinarian is retained simply to administer a State's animal health laws. In Montana, within the framework of scientific capability, funding, and personnel resources, my concerns are to administer Montana's laws responsibly and appropriately. By "responsibly," I mean to the full extent of my legal authority. By "appropriately," I mean not in excess of that authority but consistent with any ethical or moral obligations related to it. While there is not much difference among the 50 State Veterinarians as far as professional orientation goes, there is a vast difference between the State Veterinarians as far as legal authorities and social orientations go. I feel fortunate to serve in a State that, I believe, ranks among those with the very best enabling legislation combined with a functional departmental structure. Montana is severely limited, however, in terms of a strong diversified State economy and the resources that could provide.

My duty is to foster the livestock and game farm industries in Montana by the prevention, extirpation, and control of contagious and dangerous diseases. When prevention fails, extirpation and control come into play. This philosophy is the entire basis for State disease-control programs as well as Montana's State–Federal disease program agreements. Some diseases are addressed on strictly a statewide basis; others require national coordination and application. Cervid tuberculosis caused by *Mycobacterium bovis* today lies somewhere in between.

Bovine tuberculosis in Cervidae presents me with a problem that covers the full spectrum of my administrative responsibilities, from concern about catastrophic loss to domestic livestock (mainly cattle) and to the game farm industry to the possible collapse of that industry due to disease blight. I also have to assume responsibility for a dangerous zoonotic situation with real human health factors. Finally, but perhaps most visibly of all, I am deeply concerned about Montana's vast herds of publicly owned wildlife, especially cervids. These concerns are based on legal mandates that require me to avoid culpable carelessness that could cost the cattle and game farm industries millions of dollars' worth of losses. In terms of human health, there have already been several cases of human hypersensitivity in people resulting from exposure to cervid tuberculosis. What are the longrange ramifications of that phenomenon? If tuberculosis is permitted to spill into any of America's wild-cervid ecosystems, the consequences would be irreversible. Even in the absence of a legal mandate to prevent that from happening, my ethical and moral obligations to my State's publicly owned wildlife are clear. The consequences are mind boggling. I am only too familiar with the many obstacles that preclude effective disease control in sylvatic cervids. Could some act of commission or omission be a factor involved with such a spill?

I am concerned about the application of technology to tuberculosis control. More and more, the diagnostic tests we use to classify animals and herds as to disposition in a disease program are subject to question and even ridicule by the public. Tuberculosis testing is a classic example of this trend. All the good our tests have done and can do is lost when we are forced to admit we lack total precision. The concepts of sensitivity, specificity, and confidence intervals are extremely difficult to explain to a hearing officer, a jury, or a press reporter. The public often more readily accepts a recklessly broad generality on some scientific abstraction or even on some pseudoscientific observation than it does established scientific thought. Even though the truth of the reckless generalities collapses in the long term, the accuracy of our tests is an area where we are very vulnerable to challenge.

My authority to deal with tuberculosis states that the intradermal skin tests (caudal-fold and cervical sites) are the official tests for tuberculosis diagnosis in animals. Further, I may adopt as official any test recognized by USDA, APHIS, as official. I am prepared to deal with the Montana game farm tuberculosis problem using the single-strength cervical, the comparative cervical, and the double-strength cervical skin tests along with postmortem pathology and culture results for my decisionmaking (table 1, fig. 1). Likewise, I would be the first to apply a diagnostic test that would assist in reducing wastage or hasten eradication, as long as it were recognized by APHIS.

I cannot indulge fantasy or whimsy in adopting new diagnostic tests; I cannot use tomorrow's research to make today's decisions; I cannot use expensive, complicated technology to screen large populations of animals spread over broad geographic areas. My first priority in a disease outbreak is to stop any further spread as quickly as possible. My experience thus far in Montana indicates that cervical skin-testing is an excellent tool for cost-effective screening of large populations of cervids and in the classifying of herds to halt the further spread of tuberculosis. The classifying of animals in a herd confirmed as infected is more difficult, but once the diagnosis is confirmed by culture, should the classification process be so hard?

The higher the priority we assign to saving potentially dangerous animals, the more we increase the risk of perpetuating tuberculosis. This in itself results in further wastage of valuable animals for which I may also be held accountable.

I am concerned about indemnity compensation to owners of tuberculosis-infected herds. Indemnity is an important tool that assists government in rapidly eliminating an infectious disease from a herd premises. It is not a guarantee protecting the owner against all loss due to disease. The U.S. Constitution denies government the right to confiscate private property

Table 1

ELK TB TESTING
Montana 1991

	HERD OWNER	SSC		TOTAL TESTED	CCT	
		Neg	Pos		Neg Bovis	*M. bovis*
1.	MB	17	—	17		
2.	WB	115	*28	143	5	23 C
3.	AH	[illegible]	—	[illegible]		
4.	CH	21	—	21		
3.	DK	61	*13	64	5	8
6.	MK	61	—	61		
7.	JR	7	1	8	1	0
[illegible].	RS	26	—	26		
[illegible].	RS	94	—	94		
10.	GS	105	—	105		
11.	PT	33	—	33		
12.	TT	[illegible]	*6	15	2	[illegible]
13.	DW	24	—	24		
13.	JR	1	—	1		
15.	JF	2	—	2		
16.	CG	8	—	8		
18.	RC	7	—	7		
18.	BK	[illegible]	—	[illegible]		
19.	BK	2	—	2		
20.	CO			—		
21.	RP			—		
	TOTALS	590	48	638	13	35
	Deer	32	*14	46	0	14 C

* Quarantined
SSC = single-strength cervical test.
CCT = comparative cervical test.
C = confirmed through histopathology and culture of *M. bovis*.

without due process and just compensation to the owner, even for the public good.

Montana law addresses this right with a formula based on fair appraisal value with costs divided between the owner, the State, and the Federal Government. Unfortunately, at this time Montana law has capped the maximum payment from State government at $50 for a grade animal and $100 for a registered animal destroyed for being infected with an incurable disease. Currently, there is no Federal indemnity available for cervids infected with tuberculosis, and such animals have no salvage value.

What is a tuberculosis-infected cervid worth? For cervids destroyed as a sanitary measure, that is, for being exposed to a dangerous disease, in Montana no fair appraisal may exceed three times the meat value of the animal. Again, the $50 and $100 maximum caps apply. The point is that the formula under law, regardless of the dollar values, indicates that the owner should absorb anywhere from one-fourth to one-third of the true appraised value lost. But obviously the $50 and $100 cap does not allow compensation the owner is likely to consider equitable.

So, although our police powers to destroy are clearly in place, an expensive court battle and program delay should be anticipated as a result of apparent lack of incentive and adequate compensation. At this time, the only way to avoid litigation and delays in eradicating cervid tuberculosis is to get voluntary surrender of diseased and exposed animals.

Indications are that many Montana taxpayers are not willing to assume a compensation liability that approaches the $5,000 to $8,000 value of an elk today or the $300 to $800 value of a deer. Furthermore, the indications are that these same taxpayers would rather support outlawing the private ownership of cervids than spend tax revenues to compensate owners. If this attitude puzzles you, remember that a hunter can still take a wild elk for less than $25 in Montana if he or she has the mental and physical determination to do it during the elk season.

I want to make one further point on compensation: we must never allow disease to become profitable. When game farmers are encouraged to acquire wealth from the State or national treasury, all sanity will have left the tuberculosis-eradication effort for having destroyed any incentive to prevent the introduction of infection. Keeping the indemnity at two-thirds to three-fourths of each animal's value provides that incentive.

Perhaps the industry itself is the only realistic source of compensation or replacement animals that exists to resolve this issue of just compensation. Since the survival of the game-farm industry may depend on it, game farmers should continue to involve themselves in the development of a usable compensation package.

Figure 1.

OFFICIAL ORDER

SUBJECT: STOPPING MOVEMENT OF ELK IN MONTANA

It is hereby ordered that all privately owned elk on farms and ranches within the State of Montana must immediately cease any and all change-of-ownership and change-of-premises movement. This action is necessary due to the probable widespread occurrence of Tuberculosis caused by *Mycobacterium bovis* in this class of animal. The Montana Department of Livestock will grant permission to move elk only after the entire elk herd is tested negative for tuberculosis using the approved single strength cervical test technique. The game farm owner affected by this order shall engage the practicing veterinarian of his choice to perform said tests and the costs incurred shall be the responsibility of the farm owner. The results of all tuberculosis tests will be reported to the Department by the testing veterinarian using standard forms and procedures.

Done and dated at Helena, Montana this 5th day of February, 1991

By Order of the Montana Board of Livestock

/s/_____
Donald P. Ferlicka, D.V.M.
Administrator & State Veterinarian

Lastly, I am concerned about the dissemination of information on game-farm diseases. The cervid game-farm industry grew faster than government's ability to regulate it. This statement applies to State animal health and State fish and game agencies, as much as to the Federal Government. The industry itself did not have enough stature to demand the regulation that would have established its image as a responsible agricultural endeavor deserving of the public trust. Appropriate disease technology was inadequately developed for application to the game farm industry's role in traditional disease issues, and also what was known was not disseminated or applied. Bovine tuberculosis need not have become the problem in game animals that it is today. The warnings were there but not heeded. Could *Brucella abortus* infection of animals at game farms be the next disaster to befall us? Can we survive another disease disaster of the magnitude of tuberculosis? Can we survive this one?

Even though the problem of *M. bovis* infection in cervids is extremely serious, I am optimistic that as the views of government and the industry are reconciled, the mutual difficulties will one by one be overcome and the outcome will be gratifying to all involved.

Wildlife Management Agency Concerns About Bovine Tuberculosis in Captive Cervidae

E. Tom Thorne, D.V.M.; Michael W. Miller, D.V.M., Ph.D.;
David L. Hunter, D.V.M.; and Elizabeth S. Williams, D.V.M., Ph.D.[1]

Commercial raising of captive wild ruminants as an alternative form of agriculture is a growing industry in North America. This growth has stimulated concern about bovine tuberculosis among State and Federal wildlife management agencies and State agriculture agencies. Commercialization of captive wildlife primarily occurs in two forms: "game ranches," on which wildlife are confined on relatively large premises with little or no facilities for restraint or intensive management, and "game farms," where wildlife are confined in relatively small pens with facilities of varying sophistication for restraint and where the animals are intensively managed. Game ranches generally are less likely to encounter contagious disease problems because the confined wild animals are usually more dispersed and occur at a lower density than on game farms. However, detection and management of disease problems is more difficult on game ranches than on game farms.

Because legitimate zoological parks are usually surrounded by urban buffer zones, usually have resident full-time veterinary care, and experience few escapes, wildlife agencies generally do not have a great deal of concern about zoo animals presenting a disease risk to free-ranging wildlife. For the purposes of this paper, we will refer to native or exotic wildlife held on game farms and game ranches collectively as captive wildlife in general and captive cervids in particular.

All State wildlife management agencies have legislative mandates or established policies to protect, manage, and enhance free-ranging wildlife for the benefit of the people of the States. Although these agencies generally protect all species of wildlife within their jurisdiction and encourage nonconsumptive as well as consumptive uses, the agencies are largely funded through revenues generated by sales of fishing and hunting licenses.

Throughout North America there is no consistency in jurisdiction and regulation of captive cervids and their movements in commerce, especially regarding disease control. The commercial wildlife industry depends heavily upon intrastate and interstate transport and sale of wildlife. Such movements provide opportunities for movement of diseases, including tuberculosis. Veterinary Services, USDA, APHIS, has no interstate jurisdiction over captive wildlife. The only native wildlife under jurisdiction of Veterinary Services are ranched, privately owned (as opposed to free-ranging publicly owned) bison *(Bison bison)* under rules of certain disease eradication programs, such as those for brucellosis and tuberculosis. Within each State, jurisdiction for regulation of captive wildlife varies, although responsibilities generally lie with State wildlife agencies. Responsibility for animal health regulations for captive wildlife may be shared by livestock boards and wildlife agencies. These health requirements vary considerably from State to State. Consequently, those people in the commercial wildlife industry have difficulty complying with regulations or, if so inclined, have little difficulty circumventing animal health regulations.

Wildlife management agencies, especially in the West, where there is a variety of native wild ruminants, are growing more and more worried about accidental introduction of currently uncommon or absent diseases to native wildlife by way of interstate commerce in captive wildlife (Idaho Department of Agriculture et al. 1991). Although it is not their legislative mandate, wildlife agencies also share with livestock boards and traditional livestock producers a concern about protection of their State's domestic livestock. Wildlife agencies have several reasons for concern about diseases, including tuberculosis, and their interstate movement and introduction by way of captive cervids. The epidemiology, biological consequences, and host range of many diseases in captive cervids and free-ranging wildlife are poorly understood or unknown. Similarly, diagnostic tests were usually developed for domestic livestock and are generally unproven, unreliable, or unavailable for captive cervids and free-ranging wildlife.

Bovine tuberculosis is a readily transmissible and serious disease among cervids commonly held for commercial purposes, including elk *(Cervus elaphus nelsoni)* (Hadwen 1942, Stumpff 1982, Miller et al. 1991), red deer *(C. elaphus)* (Beatson 1985, Clifton–Hadley and Wilesmith 1991), and fallow deer *(Dama dama)* (Quinn and Towar 1963, Robinson et al. 1989). Although reports of tuberculosis are very rare in moose *(Alces alces)* (Hadwen 1942), white-tailed deer *(Odocoileus virginianus)* (Levine 1934, Belli 1962, Ferris et al. 1961), mule deer (Hadwen 1942), and black-tailed deer *(O. hemionus)*, they and other free-ranging wild ruminants are undoubtedly susceptible in varying degrees to the disease. Concern shown in New Zealand (documented at this symposium by M. J. Bringans and F. T. Griffin), in Canada (by M. Koller), in Britain (by J. Fletcher), and in Denmark (by F. Vigh–Larsen)—and by Veterinary Services of the United States by calling this symposium—clearly demonstrate the importance of tuberculosis in cervids. C. D. Stumpff's account (in this volume) of a 1981 tuberculosis outbreak in commercial captive elk in the Midwest and the current investigations into tuberculosis in commercial captive elk in Alberta, Saskatchewan, and other provinces in Canada (M. Koller's paper) and in Montana (D. P. Ferlicka's paper), in Colorado (Miller et al. 1991), and in other States (M. A. Essey's paper) also clearly demonstrate that tuberculosis in cervids cannot be underestimated. This is especially true if the wishes of the public to protect valued free-ranging wildlife resources and to eliminate the public health threat and economic impact of tuberculosis are respected.

[1] Dr. Thorne and Dr. Williams work in Laramie, WY, with the State's Game and Fish Department and the University of Wyoming's Department of Veterinary Sciences, respectively. Dr. Miller is with the Colorado Division of Wildlife in Fort Collins. Dr. Hunter is with the Idaho Department of Fish and Game and Bureau of Animal Health in Boise.

Currently, tuberculosis does not appear to be established as a self-maintaining disease in any free-ranging ruminant population in the United States or in Canada, with the exception of bison *(Bison bison athabascae)* in Canada's Wood Buffalo National Park (Tessaro 1986). These bison are also infected with brucellosis, and it has been proposed that the large herd of free-ranging bison be destroyed and reestablished with uninfected bison as a means of eradicating the diseases (Connelly et al. 1990).

It is not known whether tuberculosis is sufficiently contagious to become established as a self-maintained or endemic disease within free-ranging cervid populations in North America. Clearly, the disease did not become established in free-ranging wildlife during the early part of this century, when it was common in domestic livestock in the United States. Therefore, some people could argue that tuberculosis cannot become established at this time. If that is the case, then wildlife agencies should have no cause for concern about the disease in commercial captive wildlife. However, there have been major changes in free-ranging wildlife numbers and distribution and in the occurrence and hosts of tuberculosis since 1917, when the U.S. tuberculosis eradication program was initiated. At that time, the infection rate in cattle was approximately 5 percent as reported by M. A. Essey in his paper. But the disease predominated in dairy cattle, which are less likely than farmed deer to occur in close proximity to free-ranging wildlife (except possibly white-tailed deer).

The tuberculosis infection rate in cattle decreased rapidly immediately after initiation of the eradication program and steadily declined to reach the very low level of approximately 0.003 percent (Essey and Meyer 1990). In the United States, the number of tuberculosis-infected cattle was declining at the same time numbers of free-ranging wildlife were increasing, with the most marked increases in wildlife occurring during the last half of this century.

We believe that when tuberculosis was common in cattle, free-ranging wildlife populations generally were too small for the disease to become established, even if a few individuals were occasionally exposed to it by infected cattle. We do not believe that is the case now, or likely will again become the case. The sheer number of free-ranging wildlife support this conclusion. In the contiguous United States, at the turn of the century there were approximately 300,000 white-tailed deer, and by 1922, there were only an estimated 90,000 elk. Now, there are approximately 18,462,000 white-tailed deer and 714,000 elk, along with approximately 5,032,000 mule deer and black-tailed deer, 32,500 moose, and 556,700 pronghorn antelope. Including wild sheep and goats, there are nearly 25,000,000 free-ranging native ruminants in the contiguous United States (Southeastern Cooperative Wildlife Disease Study, unpublished data). Clearly, free-ranging wild ruminants are much more numerous and exist at much greater densities than they did in 1917, when the Federal tuberculosis eradication program was initiated.

It appears likely that if tuberculosis gets into U.S. populations of free-ranging wild ruminants, it could become established as a self-maintained, endemic disease. Both behavioral characteristics and management of these species would influence the likelihood of tuberculosis becoming established. Large herds of free-ranging elk could serve as examples. Based on experiences with game-farmed animals, tuberculosis is apparently readily transmitted among high-density herds of deer (Clifton–Hadley and Wilesmith 1991, Miller et al. 1991). In large herds of free-ranging elk, density is likely great enough during summer and winter to effect within-herd transmission of tuberculosis. Certainly, elk herds that are managed by artificial feeding during winter are ideal situations for transmission of the disease. Large free-ranging herds of bison are capable of maintaining endemic tuberculosis (Tessaro 1986). Most free-ranging bison reside in parks and have little contact with livestock or commercial captive wildlife, but such bison do have close contact with elk that frequently cross park boundaries. It also is possible that white-tailed deer that use yards during winter months exist at densities high enough to result in intraspecies transmission of tuberculosis.

Employees of the Nation's wildlife management agencies are now wondering not only if tuberculosis could become established in free-ranging wildlife populations but also how that might happen. Tuberculous cattle are an unlikely source because the disease is closely monitored and nearly eradicated from cattle here. In addition, where tuberculous cattle and free-ranging wildlife share the same ranges or habitat, cattle are not likely to seek out and spend time with herds of free-ranging wildlife.

At this time, it appears that the most likely source of tuberculosis transmission to free-ranging wildlife would be either native or exotic captive cervids.

Currently, adequate procedures to monitor and diagnose tuberculosis in captive cervids do not exit. Problems include difficulties gathering, restraining, and testing captive cervids; ineffective or unproven diagnostic tests; lack of tuberculosis-free accreditation programs; and inconsistent and inadequate test requirements for moving cervids interstate. These problems, combined with possible indiscriminate movements and commerce practices, have apparently allowed development of a tuberculosis outbreak of significant, but as yet unknown, magnitude and distribution in captive wildlife in Canada and the United States.

Many of the presently known or suspect tuberculous captive cervids are held in close proximity (even fence-line contact) with some of North America's largest free-ranging wildlife populations. Transmission of tuberculosis from captive cervids to free-ranging wildlife could occur through a

variety of avenues. Unlike many contagious diseases, tuberculosis could be transmitted by fence-line contact through muzzle-to-muzzle or fomite contact. Ingress and egress by free-ranging cervids, especially white-tailed deer, mule deer, and elk, could result in exposure of free-ranging wildlife while inside captive cervid pens and intra- or interspecies transmission of tuberculosis while outside the pens. Luring free-ranging wildlife into commercial facilities has been perpetrated by a few unscrupulous producers attempting to augment their herds, but most such movements have been accidental and are relatively uncontrollable.

The apparent trend in the West to confine commercial captive wildlife in large enclosures increases the opportunity for transmission of tuberculosis because these pens are never deerproof. Ingress and egress of free-ranging wildlife is a common occurrence, and escape of captive cervids is relatively frequent. Escape of a tuberculous cervid is likely the most important potential source of tuberculosis transmission from captive cervids to free-ranging wildlife. Escape need only last a few hours or days to effect transmission if an animal shedding the tubercle bacillus is involved. Direct animal-to-animal contact is not necessarily required to effect transmission. However, escaped captive cervids are likely to associate with free-ranging wildlife, greatly increasing the opportunity for tuberculosis transmission.

Once a free-ranging wildlife population, such as an elk herd, was exposed and one or more animals became infected, it would likely take a long time for the presence of tuberculosis to be recognized. And, by the time it was discovered, the disease probably would be well established within the free-ranging population. The long delay in discovery of the infection would simply be related to the facts that free-ranging wildlife populations are not and cannot be gathered for herd testing and that they are not subject to veterinary inspection at slaughter.

Discovery of tuberculosis in a free-ranging wildlife population would likely result from a biologist, game warden, or hunter submitting the carcass of a diseased animal to a diagnostic laboratory. Alternatively, a hunter might encounter the abscesses associated with advanced tuberculosis in the carcass of a harvested animal and submit them to a diagnostic laboratory. In either case, this is not likely to occur until the disease affects a large number of animals within a population.

By the time the disease were discovered and diagnosed in free-ranging populations, it likely would be affecting many animals. Eradication of this now-endemic infection by traditional test-and-slaughter techniques would be impractical as well as impossible. An entire free-ranging wildlife population could never be trapped and confined for tuberculosis testing. Wholesale depopulation of tuberculous free-ranging wildlife populations would receive little support from wildlife management agencies. There would be even less support from the public, particularly if the disease problem were perceived by the public to be due to indiscriminate game-farming or ranching practices.

We can only speculate about what might happen if tuberculosis should be accidentally introduced into one or more free-ranging wildlife populations. However, because the risk of such an event is real and because free-ranging wildlife are important in the United States, it is clearly worth considering what scenario would be likely to occur. Based upon our collective experiences and events associated with the occurrence of bovine brucellosis, a more manageable disease, in elk and bison in the Greater Yellowstone Area (Thorne et al. 1991a and b) and the occurrence of brucellosis and tuberculosis in free-ranging bison in Canada's Wood Buffalo National Park (Connelly et al. 1990), we can make a relatively reliable projection. The following scenario reflects not necessarily what we believe should happen but what we believe would occur.

Likely events leading to initial discovery of lesions in a free-ranging tuberculous wild animal were described above. Discovery of the presence of tuberculosis also would require that the submitted lesions be examined histologically with appropriate stains and be cultured by diagnosticians familiar with tuberculosis in cervids. Weeks to months would be required to diagnose the disease from the initial samples submitted.

Once tuberculosis had been diagnosed in a free-ranging wild animal, State and Federal animal disease regulatory agencies would likely request surveys to determine the extent of infection within the wildlife populations. The affected State's wildlife agency would probably agree, and hunters would participate. Surveys for tuberculosis using hunter-killed wild animals would be difficult compared to most wildlife disease surveys that depend simply upon collection of blood samples by cooperating hunters. Tuberculosis surveys would likely take the form of voluntary or mandatory presentation of part or all of each carcass of hunter-killed wild animals of the species in question from the hunt area of the wildlife involved. At check stations operated by trained technicians and veterinarians, appropriate samples for histopathologic and microbiologic examination would be collected and submitted to cooperating laboratories. Surveillance based upon histopathology and microbiology for tuberculosis would be time consuming and expensive at the laboratory level.

Hunter-kill surveys of free-ranging wildlife for tuberculosis might require several years but could show that the disease was widespread within the population. The probable response from the livestock industry and regulatory agencies would be to call for immediate depopulation of the affected free-ranging wildlife population, regardless of its size. This undoubtedly would lead to a great deal of controversy and to lawsuits. Disease control and eradication would become more of a political and legal

issue than a biological concern. In all likelihood, depopulation of the affected free-ranging wildlife population would be rejected. Given current wildlife numbers and animal rights sympathies by a significant portion of the public, depopulation simply would not be biologically or logistically possible or politically acceptable.

Simultaneously, nongovernmental environmental and animal rights groups would respond with claims that the tuberculosis problem could be solved simply by removing livestock grazing from public lands. Doing that would help reduce the possibility of transmitting tuberculosis from free-ranging wildlife to livestock but would not eliminate it because wildlife also use private lands. This course of action eventually would be rejected by politicians and administrators because of opposition of the western livestock grazing industry. Wildlife and land management agencies could be asked to compensate livestock producers for losses of grazing opportunities and for expenses related to the occurrence of tuberculosis.

Individual States' tuberculosis status under the Bovine Tuberculosis Eradication Program might eventually be affected, particularly if transmission from infected free-ranging wildlife to livestock occurred. If the risk of transmission were perceived to be great enough, the affected State might be placed under quasi-quarantine by other States acting to protect their tuberculosis-free status.

Eventually, the livestock industry and State and Federal animal health agencies would be forced to address the question, "Is tuberculosis an eradicable disease now that it is endemic in free-ranging wildlife?" This would be a difficult question to answer. If the disease were found to be ineradicable, there likely would be repercussions in the form of lost or reduced livestock and commercial captive-wildlife market opportunities by affected States. It is conceivable that the entire U.S. livestock industry would be subjected to sanctions in international markets by tuberculosis-free countries.

Finally, there could be an impact on the management of free-ranging wildlife and hunting opportunities in affected States. If public health agencies did not raise concern about the zoonotic disease potential associated with tuberculosis in free-ranging wildlife, antihunting organizations could be expected to use the presence of the disease as a convenient argument against hunting. Even if hunting of the involved free-ranging wildlife population were not halted, many hunters would be scared away because of the risk of contracting tuberculosis themselves. The end result could be an ever-increasing population of tuberculous free-ranging wildlife with concomitant ever-increasing opportunity for exposure of livestock and loss of economic benefit to the local community generated by hunting.

This sequence is admittedly speculative and may read like a worst-case scenario. However, we need only examine the ongoing conflicts and controversies surrounding Canada's Wood Buffalo National Park issue and the United States' brucellosis-related situation in the Greater Yellowstone Area to see how this scenario could become a reality. At the time of this symposium (July 1991), we can identify at least two situations involving commercial captive elk where tuberculosis transmission to free-ranging wildlife could (or may) have already occurred.

State wildlife management agencies—along with State and Federal animal health agencies, public health agencies, livestock industries, and the public—have numerous reasons for concern about tuberculosis in captive wildlife, especially cervids. Occurrence of the disease would reduce the overall health of the affected free-ranging wildlife population. Bovine tuberculosis in free-ranging wildlife could dramatically affect State and Federal wildlife management options by influencing the opportunity to use sport hunting as the preferred management tool for controlling populations, by constraining management options for translocation, by further polarizing various constituencies regarding the multiple-use concept of livestock grazing on public lands, and by creating adversary relationships and conflicts between livestock and wildlife interests and the respective State and Federal agencies representing those interests. The economic impact associated with tuberculosis in free-ranging wildlife would be great and would affect wildlife management agencies and local and State economies through loss of sport hunting opportunities. And livestock industries could be affected by changing tuberculosis-free status of affected States.

Prevention is the only viable solution for minimizing the risks presented to free-ranging wildlife by tuberculosis in captive wildlife. We believe this will require timely and strict implementation of the following strategies: (1) strict regulations on tuberculosis testing and movement of captive wildlife; (2) intensive monitoring of captive wildlife and enforcement of existing or established regulations; (3) improved diagnostic tests and methods; (4) strict penalties for violations, including liability by the captive wildlife industry for tuberculosis control costs; (5) a USDA, APHIS, Veterinary Services-administered tuberculosis eradication program for captive wildlife; and (6) improved communication and cooperation between the commercial captive wildlife industry, wildlife management agencies, and animal health agencies.

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Producers' Concerns

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The raising of exotic livestock in this country is not a new enterprise. But the intensive farming of deer for food and fiber is a very new industry in the United States. The potential for deer farming no longer represents a small niche in the livestock world. What is happening in North America goes far beyond novelty farmettes, petting zoos, private hunting preserves, consignment auctions, and the like. We are seeing large, established, conventional livestock producers diversifying from beef and dairy into deer. A revolution is occurring where the reality of deer behind fences is transforming from an exotic novelty, exotic status to true livestock status. Unfortunately, this is taking place without the benefits and discipline that regulatory protection can offer. For example, under the Federal Meat Inspection Act, venison is classified as an ingredient in processed products, like spices or dextrose. Now the USDA can call venison an ingredient, and the Food and Drug Administration can call it a rose petal. But the fact is, when people sit down to a venison dinner, they are eating red meat. There is no Federal indemnity payment program for condemned deer herds or Federal drought insurance for deer being raised side by side with other conventional livestock for the same purposes. I realize that these examples are outside the scope of this conference, but they reflect a condition, and I think it's important to establish in all our minds some inconsistencies and inequities that exist for our industry in the collective mindset of, for lack of a better word, the "establishment" responsible for such things.

The following is an excerpt from a letter I wrote Dr. Jim Glosser, APHIS Administrator, in February 1991 regarding Veterinary Services Notice "TB Testing in Cervidae," dated December 31, 1990.

> The deer farming industry in this country has recognized the serious inadequacy of the caudal fold test in Cervidae for years. As a result, members of the North American Deer Farmers Association (NADeFA) have literally searched the world over, both in the scientific literature and in operative foreign national tuberculosis eradication schemes, for an appropriate and effective program for use in our deer.
>
> In our opinion, the procedure described in the Notice does not incorporate state-of-the-art knowledge concerning tuberculosis testing in Cervidae. The comparative cervical test used as a followup to a single cervical skin test reaction and the resulting action based on the current USDA recommendation is not in the best interest of the industry or the USDA. This regime will result in the needless destruction of a large number of animals testing as false positive. In addition, no database will be produced from this method which could verify the real disease status in a given herd. This program has been applied in other countries and its shortcomings are well known and documented. The BTB test is much better in many ways than anything developed in this country, and far exceeds the specificity and sensitivity of the comparative test.
>
> The USDA as of yet has not led the way in providing an effective testing procedure for TB in deer in the United States. Until recently the technology simply has not been available, and we understand this. Now that it is, we as an industry and you as the regulatory body have the opportunity to utilize this technology for the benefit of us all.
>
> Until the last few years deer have not been farmed intensively like conventional livestock and the opportunity to practice and address animal health issues has been limited, but this is now changing. Farm raised deer are manageable and all forms of hands-on control are used by our farmers. North American deer farmers routinely record fawning, weaning, and adult weights, we vaccinate, worm, and blood test animals on a regular basis. We artificially inseminate selected brood stock and progeny test our herd bucks.
>
> Our management practices have resulted in recognizing and overcoming nutritional problems, trace element deficiencies, parasitism, and a host of other "life on the farm" problems. The records kept by our farmers rival the best managed beef and dairy herds in operation today. If all of this sounds very much like other livestock industries, it should.
>
> There is no TB outbreak in farmed deer in the United States today! There is simply the recognition of a condition which has existed for years. This recognition has come about solely through the efforts of far sighted, concerned deer farmers utilizing the available technology. This realization has occurred largely as a result of our ability and knowledge as livestockmen to intensively manage these animals. North American deer farmers have not created a tuberculosis problem in farmed deer because of our controlled agricultural practices. We have created a suitable farming environment using appropriate tests and accurate records which has allowed us to focus on and to identify problem animals.
>
> As deer farmers we are attempting to approach this issue from a broad and long term perspective, one which is not reactionary to the present state of the industry but rather is proactive in identifying the existing problems and developing solutions which will allow and encourage our industry to grow. In our opinion the Notice of December 31, 1990, is not an appropriate measure nor is it consistent with these objectives.

This paper is about producer concerns of bovine tuberculosis in Cervidae, and the concerns I've mentioned have been general, even philosophical to some extent. Allow me to be more specific. Among our greatest concerns is the "reaction to the reactions." Technical considerations aside, protocols are administered by people. Some researchers and regulators in this country insist on applying bovine data and testing procedures to Cervidae. Presumably because both cattle and deer contract tuberculosis, people do, too, but has anyone had a caudal-fold test done on him or her lately? I assume not because, among other reasons, people don't have a caudal fold. Neither do deer. The NADeFA and other industry leaders have had hard data for 3 years from all over the world concerning tuberculosis testing protocols in Cervidae. Now USDA has the same information and more, thanks in part to industry. In addition, we have complete active herd workups in infected and noninfected herds in this country utilizing ancillary tests (most notably the BTB), followup data, and whole-herd results from thousands of cases in New Zealand involving a variety of ancillary testing regimes, including the BTB and comparative cervical test. USDA has protocols, made available by other countries and the industry in this country, for whole-herd testing of known-status, unknown-status, and infected-status herds. Some organizations are still discussing the relative merits of the caudal-fold test and, more recently, the comparative cervical test as it applies to Cervidae.

Horses get up on their front legs first; cattle get up on their hind legs first. Horses face into the wind while cattle face away from the wind. Deer jump up on all fours and at times use any combination of the above, and they bed out of the wind. Morphine sulfate is a safe and efficacious preanesthetic in dogs. However, if a veterinary surgeon's first decision is to use morphine sulfate in a cat, then the veterinarian's second decision should be to find a very good defense attorney. Different species react differently to the same natural environment, to the same pharmaceuticals, to the same antigens used for testing. Species are different! We should use *deer data* to form conclusions about testing for tuberculosis in deer.

We are concerned that other livestock industries are uninformed and unaware of the facts. Unwarranted fear is a distinct possibility. Many deer farms are in fact deer and cattle farms, and the number of these dual-purpose farms is increasing. Deer are livestock just like cattle, producing food and fiber for the North American consumer. We need to find out what the real situation is regarding tuberculosis in farmed deer, and to do this we need appropriate tests. If tuberculosis is a threat for deer, then it is a threat for cattle, and vice versa. We dare not presume that transmission is a one-way street on multispecies farms. Given the relatively low numbers of cattle tested by caudal fold in this country, the effectiveness of that test, and our tremendous reliance on slaughter data for tuberculosis management in cattle, we may well discover that disease transmission will occur predominantly from cattle to deer.

We are concerned about some State game management agencies' attitudes about tuberculosis in Cervidae. We hear the argument time and again about the serious threat of diseases from farmed deer spreading to wild deer populations. Where are the data from comprehensive studies done on the status of tuberculosis in wild Cervidae in the United States? The most work has been done by Mike Hughes in Texas, where harvest data from nearly 12,000 free-roaming Cervidae of various species and ages from 1988 through 1991 have failed to yield a single case of tuberculous lesions upon postmortem exam. Since 1989, inspectors have been looking for evidence specifically because of the national issue. Given the nature of the wild deer herds in the United States, game agencies have extreme difficulty in determining simple population data, much less evaluating the extent of a low-grade, chronic, insidious disease like tuberculosis. On the other hand, deer farmers can and do test entire herds with the single cervical test in a controlled environment. We perform necropsies on animals that die of unknown causes and have a very good idea of the disease status of our herds. Now I personally don't believe that hogs should be raised in downtown Manhattan. It is also my personal opinion that a valid argument can be made against farming a deer species that is currently and naturally indigenous to a region or can interbreed with a species in that category. If alteration of the wild gene pool is why departments of natural resources have a problem with certain types and locations of deer farms, then so be it. But don't blame deer farming for problems that aren't understood in those circles or don't exit.

The deer-farming industry is concerned with the lack of regulatory consistency that exists at both the State and Federal level and the absence of Federal leadership in this area. Steve Demaris did a study of all the State and Federal agencies with regulatory jurisdiction over Cervidae in the United States. The probability of one State's regulations being the same as another's is 0.6 percent. We hear that USDA is severely hampered by State sovereignty and that USDA's authority is limited to simply "recommending." This must be so to some extent, given that a bovine tuberculosis-infected elk went from New York to Wisconsin 2 years ago from a game farm (not to be confused with a deer farm) known by both New York and USDA authorities to have had confirmed cases of bovine tuberculosis in the past. The deer-farming industry is concerned about this "our hands are tied" argument when it is used in lieu of action. Federal authorities should not be so humble in estimating their influence. A single memorandum, issued December 31, 1990, caused 11 States

within 30 days to place a ban, a moratorium, or emergency regulations into effect which were identical or equivalent to the recommendations in that hastily dispatched Veterinary Services Notice. Ten other States have since responded to that Notice in various and confusing ways. State veterinarians tell us that they can't or won't use tests not recommended by APHIS but alter testing procedures, which amounts to the same thing, in deviation from APHIS Notices. The distinction between recommendations and regulations can be a matter of semantics, not unlike that between red meat and ingredients. I do not "regulate" to my sons not to use the picture window for a baseball backstop. I "recommend" that they not use it for a backstop. It is truly amazing how effective a recommendation can be when presented fairly, explained clearly, and issued with authority.

We are concerned about the attitude, knowledge, and lack of training of some area and regional veterinarians responsible for implementing USDA policy of testing Cervidae for tuberculosis. Provincial thinking of individuals and biases notwithstanding, the lack of training in overseeing and administering USDA's own policies is abundantly clear. We are not talking about brain surgery but about a specialized, somewhat subjective testing procedure that requires the administering veterinarian to have some knowledge, a little skill, and some judgment. These requirements constitute one of the pitfalls of a skin-testing procedure and why we should seek ancillary laboratory confirmation of reactions whenever possible, and certainly as an adjunct. Interpretation and followup decisions based on field testing done by inexperienced personnel can and do determine the future for many producers.

Producers have had formal and informal agreements with regulatory personnel breached. Quarantines have been imposed without confirmation of tuberculosis in a herd by discretionary authority of persons who apparently have the power to do so. Arbitrary reversal of decisions and inconsistent application of testing procedures by the same authority have left some producers disillusioned, wary, and cynical.

A consistent, standardized, national tuberculosis testing regime and accreditation program for deer and deer alone, issued with confidence and endorsed by the industry, is a need as clear as clear can be. Without it, we can remove the word "compliance" from our vocabulary and replace it with "midnight transfers."

Deer farmers are concerned that requirements placed on our industry not be above and beyond what is normal and expected of other livestock industries under similar circumstances. Such a double standard would not be fair or acceptable since there is no evidence that tuberculosis is more profound or unusual in Cervidae than in other susceptible species. And what about the 200,000-plus ranched deer in this country? We speak so casually about testing and retesting and this test and that test. In many of these herds, owners routinely slaughter up to 20 percent of their animals. Inspected venison from these herds is a valuable adjunct to testing live animals and should be used in evaluating the disease status of these herds. Testing measures should be applied relative to the risk that these animals pose.

We are concerned about funding. Adequate government funding to establish testing protocols, accreditation schemes, and research is essential. What more can we say?

Some of what we have to deal with is new, but some is not. Utilizing many of the basics of tuberculosis control and eradication in bovines makes good sense and is appropriate—as long as certain critical differences are recognized and incorporated into a scheme for Cervidae. Rutting and fawning seasons must dictate the timing of initial screening tests and followups. The bovine schedule does not work here, but there are similar schedules that do. The single cervical test must take precedence as an initial herd screening or interstate test in lieu of the caudal-fold test. With animals that produce reactions, the BTB—or at the very least, the option to use the BTB—needs national endorsement.

Now I'll bet some of you think that the deer-farming industry is mad at you. Not at all. We're not mad—we're concerned. After what has transpired the last few years in this country, I think we have the right to be. Many of the problems concern the implementation of whatever test is used, but we have serious reservations about being limited to the use of the comparative cervical test as an ancillary test. We can see no good reason not to add the BTB to our repertoire.

All in all, industry and governmental authorities need to level with each other. Regulators have years of experience to offer in assistance, and producers have the hands-on experience and data base started to begin to get a handle on how to approach this problem sensibly and effectively. All of us need to deal in facts derived from deer data, listen to what's being said, understand differing points of view, and use conventional wisdom as a guide, not as gospel. And in the words of that famous shoemaker, just do it!

Practical Considerations for Tuberculin Testing of Cervids

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Introduction

In order to successfully carry out tuberculosis testing of cervids, three main practical considerations must be borne in mind. These are the handling of the animals, including the safety of both handlers and animals; the "windows of opportunity" that present themselves for carrying out the test, bearing in mind the biology of the various species; and ultimately the preparation of the site for tuberculin injection and its correct administration and evaluation.

Handling Techniques

General Considerations

The handling of deer species has changed markedly over the last 20 years. What was once a matter of some risk to the deer, and even to the handlers, has become more or less routine. Handling systems have evolved to the point where moving deer for a variety of purposes has become a simple part of the farming operation. As both the deer and the handlers have become more familiar with the process, the entire business of handling has become easier on both. The more the animals are handled, the easier the process becomes.

There is no doubt that the most important consideration in the handling of a deer herd is the training that the animals have had. Training implies good stockmanship, and without good stockmanship, handling will suffer. Probably just as important is the degree with which the humans involved are familiar with deer.

Human Safety

The first consideration in any handling exercise must be human safety. Neither red deer nor wapiti are necessarily aggressive, but the superior size and strength of wapiti must be respected. The handler must have an understanding of how deer use their weapons and how they signal their intent to do so. Typical signaling for deer—use of forefeet or antler threats—may be preceded by tooth grinding and usually includes a head-up look, sometimes with ears laid back and lips withdrawn, and a lunge. Some animals are naturally aggressive, and the culling of animals on the basis of temperament is considered an important part of stock selection.

The obvious weapons are the antlers. There is no doubt that anyone unfortunate enough to be caught by an aggressive male carrying his antlers is in serious trouble. This is one good reason for removing them, a practice carried out routinely on game farms worldwide.

Almost as dangerous are the front feet. Hinds and stags in velvet can use their feet most effectively. The animals rear up and box, delivering powerful blows with great speed. Deer use these weapons when defending themselves or their calves against dogs, coyotes, or rough handlers. However, occasionally human visitors as well as other animals are struck by deer staking out their place in the hierarchy.

When wapiti and red deer are being handled in close quarters, they also use their hind feet to great effect and can deliver powerful and painful blows. Biting is another method of aggression these animals employ during their competitive activities, and these cervids can inflict a nasty nip on the unwary handler.

Deer farmers soon learn to recognize the animals' threatening behavior patterns and avoid actions and postures that induce them.

Animal Differences

The basic principles of handling apply to all classes of deer, but there are differences in the details of how red deer and wapiti, fallow and white-tailed deer, stags and hinds, calves and adults, and naive and experienced animals are handled.

Stags and Bucks

The handling of stags varies with their age and the time of year. Male calves in their first winter are usually much less aggressive than older animals. During the rut, stags are at their most difficult. Not only do they tend to be aggressive toward humans, but they will fight with one another if crowded. It is important for the farmer to establish who is boss at this and all other times of year. This dominant position must be maintained by the farmer and becomes most important when the animals are worked at close quarters.

Dominant behavior by a handler is necessary in order to move males from point to point. Sometimes, a raised shovel or a cast antler held above the head may assist, but the prop, without suitable behavior by the human, will not be effective and may even invite attack. It has been suggested that the use of one of these devices is a simulation of the antler recognition system that deer species use to establish dominance without having to indulge in fights. None of these artificial dominance aids is an absolute way to ensure safety, so the handler must at all times be on the lookout. The more closely a stag is handled, the more likely it is to react aggressively.

Generally, stags in full rut should not be handled except individually because dominant ones will set upon subordinate ones and inflict injury. In the confines of a yard or handling shed, there is sometimes no escape, and attacks fatal to the subordinate deer can occur. If stags are handled at this time of year, only small numbers should be brought into the yards at any one time, and they should be drafted as soon as possible. In the shed, no more than one stag, other than yearlings, should be put in each compartment. In New Zealand deer slaughter premises, about one in five stags has broken ribs, presumably acquired when the animals fight.

When in velvet, a stag can readily be moved from pen to pen and may either be chemically immobilized or moved into a hydraulic crush that will be used for full restraint. If several males are being processed for velveting, it is advisable to have only

one animal per pen. Multiple velveting of red deer in a single large area was once a common practice but is no longer considered wise.

Bottle-raised stags are usually exceedingly dangerous during all the time that they are in hard antler. Eventually they may become unreliable at all times of year. There have been instances of such stags killing handlers, and there have been numerous "close calls." Generally, bottle-raised stags should be culled before they reach their third autumn.

Hinds and Does

Except for particularly tractable animals, hinds should not be handled during the calving season. Hinds are at their most aggressive when they have young calves, and it will not take a farmer long to recognize that there is a good deal of individual variation among animals.

Calves and Yearlings

Weaned calves and yearlings are usually the most flighty cohorts on a deer farm. More care should be taken when handling them than with any other class.

The best way to handle calves in the shed is to avoid trying to run them into the chutes and squeeze. Most chutes are designed for adult animals; calves will be able to turn around in chutes and get themselves into all sorts of tangles, making handling very difficult. As long as they are together in a small mob (6–10 animals in a swing gate system), they will crowd together and can readily be grabbed for drenching, vaccinating, blood sampling, and so forth. If a mob is being handled and released as they are treated, it will pay to keep the last two or three together until all have been dealt with.

Handling Techniques

Mustering and subsequent handling are best carried out by a small number of people, and most importantly by people using machinery with which the deer are familiar. A quiet approach is a must; strangers should be prevented from waving their arms or shouting as this behavior will only upset the deer and will prove to be counterproductive.

Active mustering can be done in several ways. The animals can be moved by people on foot, on machines (motorcycles, light trucks, etc.), or on horseback. If horses are used, it is best to acclimate both the horses and the deer to one another, which can be done by grazing them together or in adjacent paddocks. Sheep dogs have been used with great success for mustering red deer, but it is inadvisable to use them for working wapiti. Wapiti will seldom tolerate any kind of canine animal in their paddocks and have been known to pulverize coyotes with their front feet until little or nothing remains. It is counterproductive to attenuate the waipiti's natural response to predators by habituating them to farm dogs.

The flight distance of the animals to be mustered will depend very much upon the degree to which they have been handled. Good handlers can quickly assess the right distance from which to work the animals, and then the entire process becomes one of balance and steady pressure.

Raceway

Once animals are in a raceway, they will usually move away from a handler toward the yards without much trouble. In a long raceway, it is often best to close stop gates as one passes them because animals may break back. It is unwise to attempt by physical means to prevent a determined animal from going past. On the other hand, it is possible, by standing off to one side with averted eyes, to allow animals to pass. Mature animals, used to the farm, can even be drafted in this way, as a return to eye contact and an aggressive stance will most often turn back those that need to be retained. Sometimes, a single animal will become isolated from a mob. If this is a calf or yearling or a nervous adult, it may continually run up and down, not seeing the wire, and run a considerable risk of self-injury, which can easily lead to capture myopathy. The best strategy in such cases is usually to leave the animal in the alleyway, walk around it and bring a few animals back from the yards to join it before again moving the mob up to the handling area.

Yards

Drafting large mobs into smaller groups is easily accomplished in the yards. Deer tend to move along walls in the yards, and by judicious use of direct vision, they can be turned. Often an animal will turn back if the handler looks intently at it but continue if the handler avoids eye contact. In this way drafting can be carried out at weaning time or on other occasions. As an animal moves past, it must be allowed to proceed around a corner away from the handler or it will break back to join its companions. When drafting, a second person can be stationed at a gate to allow any animals that have passed the handler to enter a separate section of the yards (or to stop those that have broken past).

Shed

From the yard the animals can readily be persuaded to enter a handling complex if they are again given a chance to go around a corner. Six or 8 adult wapiti hinds, or 10–12 red deer, can conveniently be run into such an area and then separated with gates, shields, and other tools before being run into chutes.

In most cases, wapiti hinds will fairly readily move between cells in a shed system if the gates are open and they are encouraged from the side opposite the gate or from a catwalk above. Occasionally, when in the shed or swing gate, they may refuse to move into the chute. This is not usually a problem with red deer but can present a challenge if a stubborn wapiti is involved. If the gates between cells are correctly hinged, the animals can be pushed using the gate. Very occasionally, it may be necessary to enter the pen at ground level rather than working from outside it or from a catwalk or other elevated point. Some experienced farmers feel confident

about entering a shed with wapiti hinds quite unprotected, but this may not suit everybody. Others feel that it would be unwise to go in without a shield. Sliding doors, and the use of shields or a tarpaulin dropped into the compartment from above, are useful ways to augment handling of wapiti when there is a need to reduce the size of groups as they are moved into the rotunda or approach chutes.

Calves can easily be handled in shed compartments or the rotunda as a group, although they do tend to lie down on top of one another and need to be disentangled. If the amount of room that they have is reduced according to the size of the group, they will bunch together and can easily be handled for tagging, vaccination, or anthelmintic treatment.

With red deer, routine examinations and treatments are often carried out in a compartment of the shed before the animals are run into a chute or squeeze. If a rutting stag has to be handled at close quarters, a shield may be needed. For this reason, most deer sheds are now designed to allow the handlers to move around gates and doors and in with the stock. Swinging doors can be made to be closed behind the handler. Very occasionally, a hind will become aggressive in the close confines of a shed. In such a case, handlers will have to exercise caution and find a different way of dealing with the animal. There has, however, been a move away from this method as the deer can be handled in small groups in a chute, ensuring greater safety for the handler.

For handling fallow, white-tailed, mule, and axis deer, experience in New Zealand and Australia has shown that the use of light allows the animals to be handled with relative ease. If they are run into sheds and compartments that have rheostatically controlled lights set low, the deer can quickly be settled. Cracks and other extraneous sources of light should be eliminated because some deer will jump at the smallest gap. The addition of red light will allow a handler enough time to move in among the deer and draft them. If an individual or group is to be moved, this can be accomplished by turning up the light in the next compartment because the deer will usually flow toward it.

Crush

The behavior of the animals in the crush will vary according to their degree of familiarity with it. Numerous designs of crushes have been developed for different species and by different producers. As animals become acclimated to the routine of being handled and recognize that the chute and crush are merely stages in the process of return to the paddock, they are less likely to kick. Most of the common designs incorporate either a drop-floor or some sort of mechanical crush. For small deer, a keyhole arrangement for the head is also used. Head gates can be used but are not common. A homemade halter provides an easy way of restraining an animal for examination or treatment. Once animals have become used to a handling system, they will usually move through it readily.

Biological Considerations

As already indicated, there are certain times of year when testing is either dangerous or inappropriate. It may be best to avoid testing stags and bucks while they are growing velvet as there is considerable potential for damage to the developing antler, and the stress may adversely affect its final form. Similarly, males in hard antler may be dangerous to handle unless their antlers have been removed or they are run in specially designed chutes. The two main periods for testing would, therefore, be between the date of velvet removal and the onset of the rut and from the end of the rut until about the time of antler or button casting. The two windows vary from species to species and also according to latitude in some species.

Although females may be tested at almost any time, they should probably be left alone during the rut and from about 2 weeks prior to calving until the young are about 3 months old. Handling can take place between weaning (if practiced) and joining the herd after the rut until about 60–30 days before calving. Again, the timing varies according to species and locale.

It is generally believed that calves should not be tested before they are 6 months of age, but after that they may be tested at almost any time. Young males growing velvet antler for the first time may be tested if suppression or some degree of damage are not of concern. Females may be tested at any time between about 6 and 15 months of age unless they are white-tailed or mule deer that have been bred as calves and are due to deliver when they are 13–15 months old.

Test Administration

In North America, the diagnostic test approved for first evaluation in live animals is the intradermal tuberculin test using bovine PPD. A comparative test is also used, but the actual administration of the test differs only in terms of the number of test sites.

Site Selection

Intradermal testing for tuberculosis in cattle has long been practiced by injection of tuberculin into the caudal fold of the tail. This test has been useful because it is easy to administer, requires little site preparation, and poses minimal risk for the operator. When the disease was first diagnosed in New Zealand deer herds in 1978, an early response was the evaluation of different sites at which to administer the tuberculin. Of the sites tested, the midcervical region was found to be the only one of any value. The caudal-fold test was quite unreliable. Sensitivity of the test at that site was judged to be about 21 percent, and further caudal-fold testing was abandoned when it became evident that the midcervical region was the most reliable. Unfortunately, until the end of 1990, the caudal-fold test was virtually the only one employed for cervids by State and Federal veterinarians in the

United States. Since 1988, the site for intradermal testing in Canada has been the midcervical region. In the late summer of 1990, Canadian authorities banned the import of deer species from the United States pending improved testing.

Site Preparation

Good preparation of the midcervical site for tuberculin injection is essential. All hair must be removed from an area at least 4 by 4 inches (10 by 10 cm), especially when testing is conducted in winter and the heavy mane may obscure the site. The clip must be similar in quality to that for a surgical procedure, and can be achieved by the use of a #40 Oster blade, or its equivalent, as long as it is maintained in excellent condition. In winter, the use of two blades may be required. Site preparation with scissors is usually unsatisfactory.

Tuberculin Injection

Various types of tuberculin have been used as the antigen, the type not being important in terms of its practical application. The solutions should be injected using a 26- or 27-gauge needle into the dermis of the animal. In the United Kingdom and New Zealand, a standard syringe designed specifically for the administration of 0.1 mL of tuberculin is employed. Good lighting is important because the skin in this area may only be from 1 to 3 mm thick, and the mistake of giving a subcutaneous injection is easy to make. If the injection has been properly made, a small bleb, which can be both seen and palpated, will appear in the skin. Making a ring around the injection site with a black felt-tip pen is a useful aid that will pay off when the test is to be read. In the United Kingdom, measurement of the skin with accurate calipers is carried out before the tuberculin is injected. If a comparative cervical test is to be performed, the sites must either be on opposite sides of the neck or at least 4 inches (10 cm) apart. It is absolutely essential to record which site is which and also to record the exact skin thickness before administering the injections.

Reading the Test

When the test is read, lighting conditions must be excellent. Often a positive reaction can be seen from a distance. Reactions may vary from localized, firm, indurated swellings at the injection site to a more generalized edema around the area. Evaluation may also involve measurement of skin thickness, but in New Zealand, the United States, and Canada, palpation is considered to be an adequate means of measurement. The skin can either be picked up between thumb and finger and felt for increased thickness, or the hand can be run over the area. In either case, the animal may be sensitive to the touch, or local heat may be detected. In the United Kingdom, calipers are commonly used for measuring both before and after tuberculin administration. It is important to note that calipers should be accurate. Those designed to ensure a constant pressure are considered the best. Ball calipers may not be accurate enough as they do not generally calibrate more accurately than to 2 mm. In a single evaluation, repeatability of measurement may vary by as much as 0.4 mm.

Interpretation of any thickness increase varies according to the governing jurisdiction and may be based upon the perceived likelihood of infection being present. For maximum sensitivity, any visible or palpable thickening should be regarded as positive. In many cases, increases of 2 mm or greater are considered positive; in others, any increase at all is taken to mean that infection may be present. In New Zealand and the United Kingdom, two standards may be used, depending upon the status of the herd. Under normal circumstances, a swelling of 2 mm or more is taken as positive. If the herd is known to be infected, interpretation is more severe: any swelling greater than 0.5 mm is interpreted as positive. Interpretation of the test in North America is generally severe, with reactions of any kind leading to a designation of suspect status for the herd.

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Tuberculosis Control in the New Zealand Deer Industry[1]

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Tuberculosis in New Zealand deer, caused by the bacterium *Mycobacterium bovis*, was first recognized in feral animals in 1970 and in farmed deer in August 1978 (Livingstone 1980). Since the 1970's, the deer industry has taken the initiative in implementing options for control as various diagnostic technologies were quantified and as farmers became united in their desire to control the disease. The development of this control program culminated in January 1990 with the introduction of a compulsory control program for all herds.

This paper outlines the industry's progress to date in controlling tuberculosis and develops information initially presented to the New Zealand Veterinary Association Deer Branch conferences held in 1987 and 1990 (Corrin 1987, Carter 1990). (All 1990 statistics cited here are based on provisional data drawn from the Ministry of Agriculture and Fisheries–Quality Management's deer–tuberculosis data base.)

Measuring Progress

Given the complex epidemiology of tuberculosis in New Zealand, it is necessary to examine a number of parameters to gauge the progress of the control scheme. Traditional measures, such as the number of herds on movement control and the number of deer showing a positive reaction to testing, give only a crude outline on the occurrence of disease. Indicators relating to the dynamics of the disease (incidence, risk assessment) give a more accurate assessment of progress over time.

Movement Control

The number of herds placed on movement control following the diagnosis of tuberculosis peaked in July 1986 (478), and figure 1 shows the decline and stabilization that has since taken place. As of January 31, 1991, 278 herds were on movement control, 64 percent (179/278) of which were classified as infected. That is, a clear whole-herd test had not yet occurred following the diagnosis of a tuberculous deer.

Figure 1 traces the number of movement-controlled herds in New Zealand on December 31 of the years 1985–90 and on January 30, 1991. As would be expected, the distribution of these herds between areas of New Zealand classified as Special TB Control and Surveillance Zones is not random. Seventy-one percent (197/278) are located within the Special TB Control Areas (table 1)—an increase of 10 percent from December 1988.

Although the January 1991 movement control figure represents 4.4 percent of all herds, 10 percent of the herds in Special TB Control Areas are on movement control, compared to 1.9 percent in Surveillance Areas. In 1989, these figures were 14.6 percent and 3.2 percent, respectively.

Using the following equation and data in table 2, an incidence figure for movement control may be calculated:

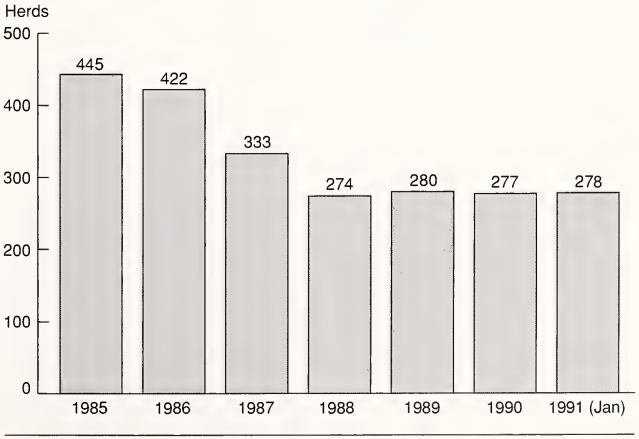
$$\text{Incidence of MC herds} = \frac{\text{Number of new MC herds for 1990}}{\text{Total herds} - \text{Number of MC herds at June 1990}} \times \frac{100}{1}$$

Again, the incidence of herds going on movement control reveals a significant difference between Surveillance Areas and Special TB Control Areas; the incidence of MC herds in Surveillance Areas is 0.12 percent, compared to 2.6 percent for the Special Control Areas. Expressed as relative risk, a herd in a Special TB Control Area was at least 21 times more likely to come onto movement control in 1990 than 1 in a Surveillance Area.

In terms of attributable risk within Special TB Control Areas, 25 herds in 1,000 will break down because of factors unique to these areas, presumably as the result of a feral source of infection. Only 1 in 1,000 herds will go onto movement control because of factors common to both Surveillance and Special TB Control Areas.

Figure 1

Number of tuberculous herds in New Zealand under movement control as of December 31, 1985–90, and January 31, 1991



[1] The information in this paper was originally published in the proceedings of a symposium on tuberculosis held at Palmerston North, NZ, in April 1991. The proceedings were published (publ. 132, ISSN 0112-9643) by the Foundation for Continuing Education of the New Zealand Veterinary Association.

Table 1—Herd distribution and movement control (MC) status as of January 31, 1991

	Total herds	MC herds	% Herds on MC
North Island			
Surveillance	2,464	47	1.9
Special TB Control Areas	967	108	11.2
NI total	3,431	155	4.5
South Island			
Surveillance	1,873	34	1.8
Special TB Control Areas	994	89	8.9
SI area total	2,867	123	4.3
New Zealand			
Surveillance	4,337	81	1.9
Special TB Control Areas	1,961	197	10.0
NZ total	6,298	278	4.4

Table 2—Movement control (MC) statistics, 1990

	New MC herds in 1990	Total herds, Dec. '90	MC herds, June '90
Surveillance	5	4,356	83
Special TB Control Areas	46	1,960	190

Reactor Rate and Incidence

When a plot of the tuberculosis reactor rate for deer (fig. 2) is examined, it must be interpreted with caution due to the redefinition of the term "reactor" over the years and the influence of the marketplace. In 1985, reactors were classified as any deer positive to a standard tuberculosis test. Now the definition includes any deer positive to at least one test and directed to slaughter by the Ministry of Agriculture and Fisheries. That is, an allowance has been made for nonspecific reactivity to bovine tuberculin. Even today's definition of the reactor rate has been influenced by the marketplace: farmers who do not wish to hold test-positive deer for retesting are sending them to slaughter.

Even making allowances for these difficulties in interpretation, there has been a steady decrease in the reactor rate over the last 4 years, a period when veterinarians have had more discretion over retesting. As occurred for movement control, a more detailed evaluation of the 1990 testing data in table 3 indicates that the reactor rate varies markedly between Special TB Control Areas and Surveillance Areas: 0.54 percent and 0.29 percent, respectively. A similar trend was reported in 1989 (Carter 1990).

The lesion reactor rate for 1990 was 25 percent (17 percent in Surveillance Areas, 32 percent in Special TB Control Areas), compared to 39 percent (838/2,144) for 1989. Although the validity of a test will decrease as the incidence of disease decreases, the effect of farmers' slaughtering test-positive deer rather than waiting for retests is likely to act as a confounding variable in this case.

The incidence of reactors and tuberculosis based on population rather than numbers tested also indicates a steady decline despite the deer population increasing approximately 2.5 times since 1986 (table 4).

Accreditation Scheme

Since the introduction of the voluntary accreditation scheme in August 1985, steady progress has been made in accrediting herds (fig. 3).

From January 1990 to January 1991, the percentage of accredited tuberculosis-free herds has risen more than 12 percent, to 41.5 percent (2,613/6,298). With only 5 percent of all test-eligible herds yet to have their first whole-herd test (as of the end of 1990), the percentage of accredited tuberculosis-free herds is expected to continue to increase rapidly through 1991 and 1992.

South Island herd owners are moving more rapidly toward accreditation than their North Island counterparts; at the end of 1989, there was a difference of 2 percent between the 2 groups (30.2 percent and 28 percent, respectively). This gap has now increased to 6 percent. South Island herd owners have also made more rapid progress in getting their herds off movement control.

Figure 2

Tuberculosis reactor rate (percent of New Zealand herds), 1985–90. The reactor rate equals the number of reactors divided by the number of standard tests applied in the calendar year

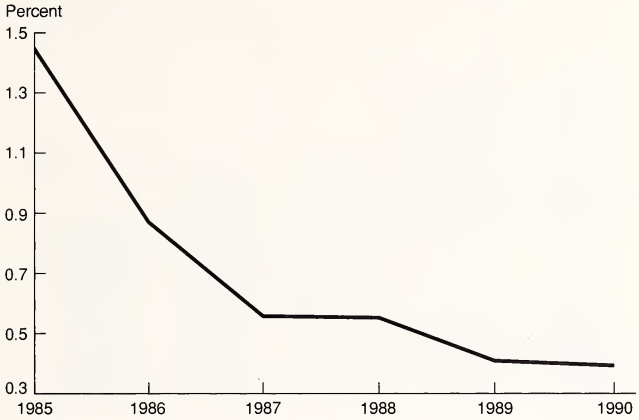


Table 3—Tuberculosis testing data, 1990, from New Zealand

	Deer given standard tests	Deer positive on standard tests	Reactors	Reactors with lesions	Lesion nontest deer (clinicals)
Surveillance Areas	321,644	5,607	954	160	79
Special TB Control Areas	201,874	5,263	1,099	356	114
NZ total	523,518	10,870	2,053	516	193

Use of Tests

Three tests are approved by the Ministry of Agriculture and Fisheries for the diagnosis of tuberculosis in live deer: the standard bovine tuberculin test, the comparative cervical test (CCT), and the lymphocyte transformation test. For the last 5 years, both the standard test and the CCT have been used with increasing frequency while the use of the lymphocyte transformation test has stabilized since its release in 1987 (figs. 4–6).

When the CCT was approved for use in 1986, its primary function was as an auxiliary to the standard tuberculin test, i.e., for the retesting of deer reacting positively to the standard test where there were no epidemiologic data to support a diagnosis of tuberculosis. However, on the basis of data in figure 5, veterinarians have identified a clear role for the use of the CCT as a primary or "first-up" test. In 1990, the number of deer undergoing the CCT exceeded the number of deer positive to the standard test by 3.3 to 1, an increase over the figures for 1989.

Although the incidence of tuberculosis continues to decline, the promotion of the CCT into a primary test is being assessed critically. Under field conditions, the CCT has the lowest sensitivity of the three approved tests. Maintaining quality control is difficult, given the complexities of administering and reading the CCT and the number of operators using it.

In addition to the testing of live deer, 123,102 animals were inspected at slaughter during 1990. When this fact is taken into account, approximately 68 percent of the population was subjected to active surveillance for the disease during 1990. Final testing statistics for 1989 indicate that the level of surveillance was in excess of 77 percent.

Costs

An approximate cost for operating the tuberculosis control scheme in 1990 may be calculated on the basis of the following assumptions:

Standard bovine tuberculin test $3
CCT $10
Lymphocyte transformation test $120
Loss per reactor $190 (75 percent of market value)

Testing costs amounted to $2.1 million (N.Z.) while the estimated financial loss through reactors was $400,000. The Ministry of Agriculture and Fisheries' administration costs for the scheme were $500,000, and the industry's share of Animal Health Board expenditures for possum control was $630,000. Total costs add up to $3.63 million for an industry that earned $101 million from exports during the 1990 calendar year.

Table 4—Incidence of tuberculosis in New Zealand, 1986–90

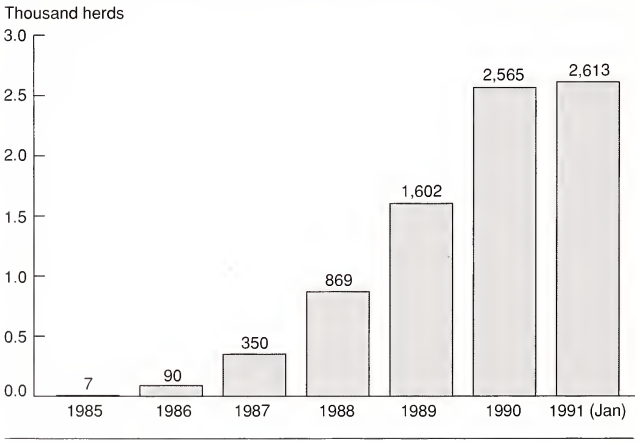
	Deer population	Reactors	Reactor incidence (%)	Reactors with lesions	Lesion nontest deer (clinicals)	Tuberculosis incidence[1]
1986	392,154	2,390	0.61	NA	234	Unknown
1987	500,397	1,870	0.37	NA	NA	Unknown
1988	606,042	2,132	0.35	NA	NA	Unknown
1989	780,066	2,144	0.28	838	263	0.14
1990	951,000	2,053	0.22	516	193	0.08

NA = not applicable.

[1] Tuberculosis incidence is calculated as the number of reactors with lesions plus lesion nontest deer (clinicals) divided by the total deer population. This definition yields an underestimate of the true incidence but removes the confounding variable of the influence of the marketplace on the number of reactors.

Figure 3

Number of accredited tuberculosis-free herds in New Zealand as of December 31, 1985–90, and January 31, 1991



Summary

The deer industry is continuing to make significant progress in controlling the incidence of tuberculosis in deer. Although the rate of progress can be expected to stabilize, the percentage of accredited free herds will increase over the next 2 years [1991–93] until a point of equilibrium is reached with infection in the feral environment.

For the overall success of the program, a focus must be maintained on finding and improving control strategies for feral animal populations. However, from the farmers' perspective, increasing pressure is likely to be applied to improve the validity of a primary test that is economically viable to the industry.

Figure 4

The number of standard bovine tuberculin tests administered in New Zealand, 1985–89, with provisional totals for 1990

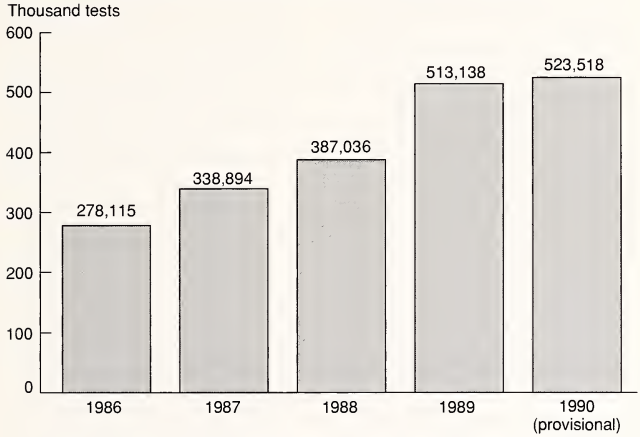


Figure 5

Number of comparative cervical tests for tuberculosis administered in New Zealand, 1985–89, with provisional totals for 1990

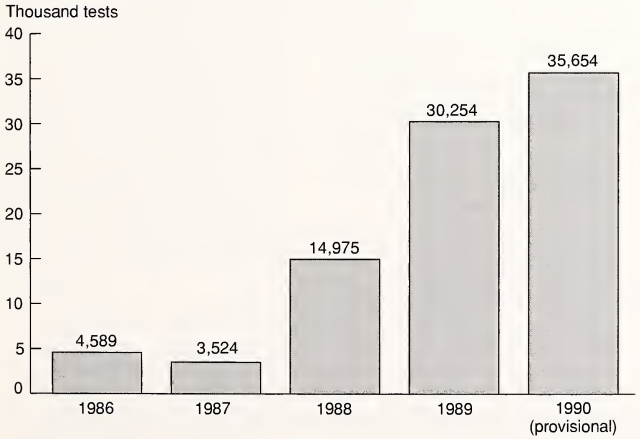
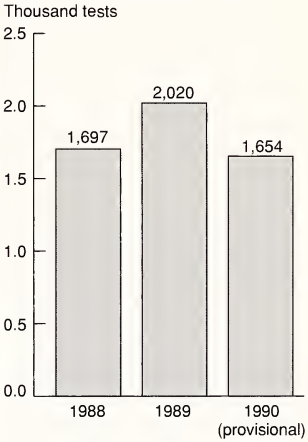


Figure 6

Number of leukocyte transformation tests for tuberculosis administered in New Zealand, 1988–89, with provisional totals for 1990



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Recommendations of the International Conference on Bovine Tuberculosis in Cervidae

Group 1—Cervid Herd Testing

Chairperson: G. H. Frye
Cochairperson: D. P. Ferlicka

Group 1 had approximately 35 participants who appeared to be a representative sample of the various interests attending the conference. The group approached its assigned topics, "Herd Testing" and "Followup Procedures and Standards for Accreditation," with individual position statements and a wide-ranging discussion of issues relating to these topics.

Among these varied issues were the difficulties inherent in testing for accreditation, diagnosis, movement, or any other purpose, Cervidae held on large pastures. One example cited was the 250,000 animals on 20,000-acre pastures owned by members of the Exotic Wildlife Association. These and similar herds do not lend themselves to any testing plan that would require roundup and restraint of individual animals. Since 6,000 to 8,000 of these animals are slaughtered under inspection each year, the group thought consideration should be given to using slaughter surveillance as the routine method of detecting tuberculosis in these, and similar, large herds. There was general agreement that "ranch herds" and "farm herds" should be considered separately in recognition of their different handling problems. The difficulty that herds have in complying with the import requirements of States that require Cervidae to come from test-negative herds is also a function of herd size. The creation of satellite herds to ease the burden of complying with these requirements was proposed as a possible solution and received tentative acceptance by State Veterinarians in the group.

Many of the herd owners present expressed general dissatisfaction with tuberculin testing procedures outlined in the December 31, 1990, APHIS memorandum. The feeling was that compliance with these requirements would put them out of business.

There was strong support among owners for use of the blood tuberculosis (BTB) test to confirm tuberculin test results in herds and in individual animals. The group devoted most of its time debating the use and merits of various tests and testing procedures. The conclusion was that each had its advantages and disadvantages and that none answered all of the unique requirements for testing Cervidae.

The group recognized there is critical need to determine the role the BTB test will play in tuberculosis diagnosis and to compare its efficacy with that of the tuberculin skin test. The group also recognized that the lack of indemnity will continue to have an adverse effect on the proper evaluation of affected herds and on the elimination of animals from these herds needed to free them from disease. The current value of cervids makes the sacrifice of even a few animals for diagnostic purposes financially unacceptable for most owners.

The discussions recognized the need and clearly showed support for practical, effective procedures for controlling tuberculosis in cervid herds and for a herd accreditation program "that means something." The group's proposals for meeting these needs are as follows:

Testing Cervid Herds Not Known To Be Affected

1. All animals over 6 months of age shall be tested with the single-strength cervical (SSC) test, using USDA, PPD Bovis, 0.1 mL.

2. The herd test shall be completed within a 60-day time period.

3. The herd test is negative for tuberculosis (1) if all test-eligible animals are negative to the SSC test; *or* (2) if all animals that show reactions on the SSC test are retested with the comparative cervical test (CCT), the BTB test, or both, with negative results. (The choice of test is at the option of the herd owner); *or* (3) If all reacting animals are slaughtered and appropriate tissues are examined histopathologically and bacteriologically without showing evidence of tuberculosis, the herd test will be considered negative.

4. Herds not meeting the criteria for negative status are handled as infected herds.

Testing Cervid Herds Known To Be Affected With Tuberculosis

1. All animals in the herd are tested at a minimum of 60-day intervals using the double strength cervical (DSC) test and the BTB test.

2. All animals testing positive on the skin test or BTB are to be slaughtered and examined as appropriate for tuberculosis.

3. A herd test is designated as negative for tuberculosis when all test-eligible animals are test negative or if all cervical and BTB test-positive animals are negative on culture and histopathological examination.

4. The herd would be eligible for quarantine release following 3 negative herd tests, the first at least 3 months following removal of the last reactor from the herd and the second at least 6 months following the first negative test, and the third following by at least 6 months from the previous negative test.

Note: It was proposed that all testing in infected herds be at State or Federal expense and that owners be compensated for reacting animals at fair market value.

Accreditation of Cervid Herds

By Herd Testing—

1. Test all animals over 6 months of age within a 60-day period using the SSC test.

2. The herd test would be designated as negative if all animals were negative to the cervical test or if all animals showing reactions on the cervical test were retested and found negative using the comparative cervical test, the BTB test, or both.

3. Three consecutive negative tests in a 2-year period would qualify the herd for Accredited Tuberculosis-Free status.

To maintain accredited status, the herd must pass a negative test every 2 years.

By Slaughter Surveillance—The requirements and feasibility of this method of accreditation will need to be determined.

Group 2—Movement Restrictions

Chairperson: Victor F. Nettles, Jr.
Cochairperson: Dennis J. Carr

This work group discussed a variety of issues concerning movement of captive ungulates and would like to present the following conclusions:

1. At present, the group felt most comfortable addressing the problems of tuberculosis monitoring and movement in Cervidae. It was recognized that other families of captive ungulates also are used in "game farming" as well.

2. The members of the group felt that the only possible way to maintain uniformity in controlling movement of potentially infected Cervidae was for USDA to develop a Federal program. We strongly recommend that USDA obtain authority over tuberculosis control in Cervidae and that this program should parallel programs in place for cattle and bison. Regulations and guidelines should be published in a Uniform Methods and Rules. An accreditation program should be developed for captive deer herds. However, the tuberculosis status of any given State for Cervidae should not affect that State's tuberculosis status for cattle and bison until infection in the latter species is proven.

3. Every State should obtain the authority to quarantine cervid herds known to be infected with tuberculosis, known to have been exposed to the disease, or suspected to harbor it. Every State should have authority to regulate the use of Cervidae in captivity.

4. Animals moved interstate must have a certificate of veterinary inspection (health certificate) and an entry permit from the State of destination. All animals must be identified with official ear tags (type to be determined by USDA, APHIS) or tattoo. These identifications shall be noted on the health certificate. Official test animals shall be 6 months of age or older.

5. Cervidae could move among deer farms, large high-fence Texas-style pastures, exotic animal auctions, accredited zoos, small zoos/menageries, or foreign countries under at least seven different scenarios. Four basic situations seem to cover all possible situations, and recommendations for movement regulations were made for each type:

- **Situation 1. Animals originating from an accredited herd.** The group is optimistic that herd accreditation by appropriate testing and herd management will be developed for Cervidae. Animals from accredited herds could move interstate with only a health certificate and permit entry from State of destination. No tuberculosis testing would be required before entry.

- **Situation 2. Animals that would qualify as a "tested herd."** A "tested herd" would be defined as a herd that had received a negative whole-herd test in the past 12 months. Individual animals from such a tested herd could move on the basis of one negative test performed >90 days after whole-herd test and <60 days prior to shipment. The receiving State would have the option of postentry quarantine and testing.

- **Situation 3. Animals from a herd of unknown status,** such as a partial shipment from a large free-ranging herd. Such animals must be held separate from all others during the conduct of two negative tests before entry. The first test would be made 90–180 days prior to shipment. The second test would be <60 days prior to shipment. The receiving State would have mandatory postentry quarantine and a negative retest required between 120 and 180 days postentry.

- **Situation 4. Known infected or exposed herds.** Animals from herds of these types would be allowed to move interstate for slaughter only, accompanied by permit.

6. The aforementioned guidelines for interstate shipment could be modified as necessary and applied to intrastate movement or even international import.

7. Where several species of Cervidae are commingling, all animals shall be considered members of the same herd.

8. Auction sales shall be prohibited from releasing animals until the buyer has a permit from the State of destination.

9. Testing requirements shall be exempt for animal movement between AAZPA-accredited zoos, provided that adequate quarantine status at the recipient zoo is maintained to prevent outside spread of tuberculosis. Movement of animals out of zoos to other types of animal owners shall be subject to all proposed regulations.

10. State wildlife agencies can move bona fide wild ungulates without testing after appropriate consultation with the State Veterinarian.

11. The above recommendations are being made in full recognition that tests needed to implement them are not infallible. It is hoped that better methods will soon become recognized and available. Furthermore, several members of the group foresee considerable hardship produced by some of these recommendations. But there

does not appear to be an easy answer to eliminating tuberculosis from the captive cervid industry. In fact, considering the current programs in some other foreign countries, many in the group suspect that more rigid regulations eventually will be needed.

Group 3—New Test Technology and Research

Chairperson: C. O. Thoen
Cochairperson: T. J. Hagerty

This work group made nine recommendations:

1. Tuberculin tests for detecting tuberculous zoo animals need to be validated.

2. Tuberculin skin tests are needed for free-ranging wild animals.

3. Hunter surveys are needed to obtain information on prevalence of tuberculosis in wild animals.

4. Rapid serum tests (ELISA) for elk, deer, and other animals need to be developed.

5. Evaluation of BTB (LBA), gamma interferon assay, and other cell assays needs to be done.

6. The comparative cervical test (CCT) needs to be validated in elk, deer, and other captive wild animals.

7. The single cervical test (SCT) is an internationally recognized test (reported to be 85 percent sensitive and 99 percent specific in deer in New Zealand), but it needs to be validated in deer and elk in North America.

8. Other diagnostic procedures that need to be developed are:

- Use of monoclonal antibodies for detecting antigen in tissues.

- Intradermal skin test antigens with improved sensitivity and specificity.

- Use of DNA probes and polymerase chain reactions for the identification of mycobacteria.

- Identification of genes associated with host resistance.

- Use of restriction endonuclease analysis for epidemiologic associations.

9. Experimental studies are needed to obtain information on pathogenesis and development of immune responses for use in evaluation of "new" diagnostic tests.

Funding should come from these organizations:
North American Elk Breeders Association,
North American Deer Farmers Association,
U.S. Department of Agriculture,
Exotic Wildlife Association, and the Morris Foundation.

Collaborative investigations involving international organizations are encouraged:
APHIS, USDA
Human health officials
Universities
Private industry
American Association of Zoo Veterinarians

Group 4—Compensation to Owners for Animals Destroyed Because of Tuberculosis

Chairperson: Sam Withiam
Cochairperson: David Whittlesey

Background

The current outbreak of bovine tuberculosis in cervids is an emergency veterinary health issue requiring rapid controlling measures to identify, isolate, and eradicate the disease. Failure to act immediately potentially endangers other livestock and wildlife populations.

A Long-Term Approach

Farmed and ranched cervids are an important emerging industry that needs to be recognized in Federal and State statutes and regulations as are the industries that raise other livestock for production of food and fiber. To this end, industry, in cooperation with government, will initiate measures to establish a program that provides for surveillance, traceback, and disposition of cervid stock infected with tuberculosis and other diseases. Uniform Methods and Rules should be drafted and submitted to the U.S. Animal Health Association. USDA, APHIS, should initiate action within USDA to recognize farmed deer as domestic livestock under existing regulations. Industry commits to supporting government efforts in the legislative process to make this a reality.

The Immediate Effort

Infected herds of elk, red deer, and fallow deer have been identified in six States. Herds are in quarantine under State jurisdiction without enabling Federal regulations. Further efforts to remove infected animals have been voluntary on the part of owners and who did not receive compensation for their losses. A similar problem faced the bison industry 10 years ago at about the same stage of growth as the cervid industry enjoys today. Fair and equitable compensation, cooperation between industry and government, and prompt and decisive action effectively controlled this outbreak in a relatively short period.

Without the longrange program outlined above, the group recommended the following actions:

1. Embark on a program of compensated test-slaughter or depopulation in gross cases of cervid herds currently known to harbor tuberculosis. The necessary funding is to come from APHIS, States, and industry. APHIS is to use existing discretionary funding with expenditures authorized through emergency regulations if required. In States that do not rely wholly on the Federal tuberculosis compensation

program, a similar approach is to be taken. Industry funding is to be provided through associations and individual stock owners as appropriate.

2. Industry and the Federal and State Governments shall jointly establish fair and equitable compensation levels, and industry associations will actively encourage members to accept settlements.

3. Industry associations will encourage compliance with uniform standards of tuberculosis accreditation jointly developed by industry and government.

Surveillance Through Inspected Slaughter

In herds maintained principally for the production of venison, inspected slaughters by State and Federal agencies are an essential part of the surveillance program. Slaughter inspection has proven to be the most effective way of identifying tuberculosis in cattle herds. To encourage broader use of these services, it is recommended that APHIS ask USDA, Food Safety and Inspection Service, to waive the voluntary inspection fee currently charged producers.

Conclusion

This working group is deeply concerned that without prompt, fair, and equitable action, the current potentially minor outbreak of tuberculosis in cervids could escalate to unmanageable proportions due to unauthorized transfers and release of stock.

Group 5—Tuberculosis in Zoo Ungulates

Chairperson: Murray E. Fowler
Cochairperson: Wilbur Amand

The group expresses its appreciation for the open and frank discussions on ungulate tuberculosis that have taken place at the invitation of USDA, APHIS. The group believes that there needs to be a more uniform application of regulations at both Federal and State levels. Achieving this uniformity may require that periodic training programs be provided to veterinary medical officers so they may understand the unique situations that exist in dealing with zoo ungulates.

There are few experiences upon which to base judgments. It is unlikely that there will ever be statistical documentation as to what constitutes a tuberculin reaction and what constitutes a nonspecific response. Flexibility in judgment is necessary in test interpretation to avoid taking unwarranted action in special cases.

The following statements and recommendations are submitted from the group:

1. We support the concept of tuberculosis surveillance and control.

2. We believe that currently there is no viable testing program that will definitively identify antemortem tuberculosis in an individual animal, across the wide range of zoo ungulates.

3. It is our recommendation that, in the absence of a reliable test, a cervical skin test should be performed on ungulates prior to being shipped and that the results of the test should be interpreted on the basis of herd history, pathology data, and supplemental tests. The positive response of one animal to a single cervical test may not necessarily warrant a whole-herd testing.

4. For tuberculosis test responders that are making a unique species contribution, we recommend that, as an alternative to euthanasia, consideration be given for treatment in accordance with a protocol worked out through the cooperation of regulatory agencies and the affected zoo.

5. We recommend that zoos, researchers, and regulatory agencies work together, financially and philosophically, to develop and evaluate reliable testing procedures that will be sensitive to the uniqueness of zoo ungulates.

6. We acknowledge that different tiers of institutions are referred to as zoos, including American Association of Zoological Parks and Aquariums (AAZPA)-accredited zoos, nonaccredited zoos, and other private collections. Rulemakers should take into account the internal, self-imposed health controls within these institutions.

7. We urge development of a spirit of cooperation and interaction between the zoo community and regulatory agencies. The American Association of Zoo Veterinarians (AAZV) stands ready to assist in the development of protocols or plans in cooperation with any government agency. AAZV will also inaugurate a program to establish an inhouse tuberculosis surveillance protocol for use by zoo veterinarians.

Group 6—Human Health Concerns

Chairperson: E. A. Fanning
Cochairperson: Maria Koller

Introduction

The control of tuberculosis in animals is designed for the primary purpose of protecting people from zoonotic infection. Rates of *Mycobacterium bovis* isolation from human tuberculosis cases ranged from 5 to 10 percent before policies required pasteurization of milk and eradication of infected herds. As a result, *M. bovis* is rarely reported as the cause of tuberculosis in humans in the western world.

Recognizing that the current epidemic of tuberculosis in the cervid industry imposes a small but significant risk of infection on the people who handle these animals, we recommend that the mode of infection and the means to prevent its occurrence and to treat it prophylactically be clearly outlined for all involved.

Recommendations

We have recommended the following precautions to be followed to prevent zoonotic spread of *M. bovis:*

1. Notify human health officials when *M. bovis* is isolated from any animal.

2. Perform contact followup on any *M. bovis* culture-positive animal handlers by administering a 5 tuberculin units PPD intradermal skin test immediately. Persons having a positive tuberculosis skin test should be observed for symptoms and have a chest x-ray and sputum culture. Antimycobacterial medication should be offered as appropriate.

Persons having a negative tuberculin skin test should have the test repeated after 3 months.

3. For managing known *M. bovis* culture-positive herds designated for destruction, minimize human contact and encourage handlers to wear close-fitting masks that filter to 5 micron size. Avoid hosing the area and do so only after bleach or 2-percent glutaraldehyde decontamination (15 minutes). Avoid using a buzz saw. Perform a tuberculosis skin test before and 3 months after contact.

Assess skin test reactors by inquiry into past history and results of chest and sputum culture. Offer treatment as indicated.

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